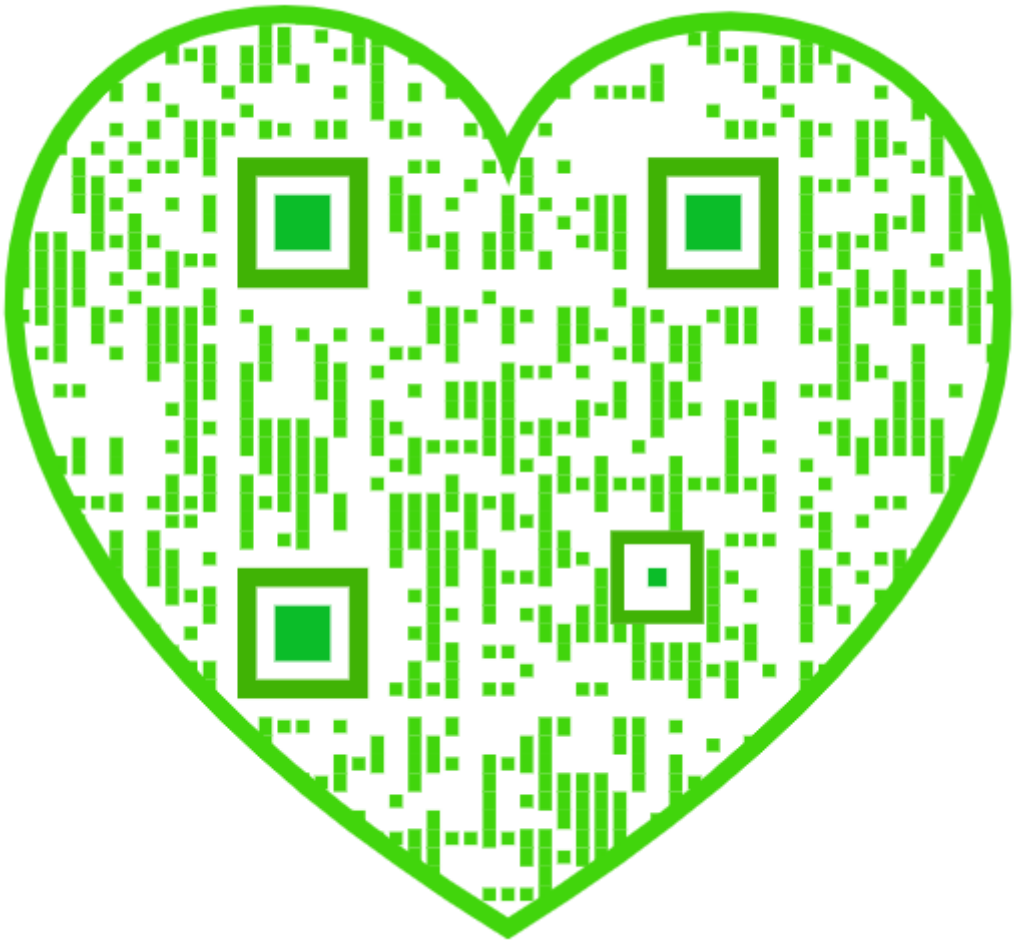

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MODERN PRACTICE IN MINING

VOL. II

THE SINKING OF SHAFTS

BY

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GENERAL

PREFACE

THE sinking of shafts for the purpose of opening out and developing mineral deposits constitutes one of the most important branches of mining, and although a vast amount of information respecting such operations is disseminated throughout the volumes of the Transactions of the various mining institutions, and excellent chapters are devoted to the subject in many text-books on mining, yet, so far as the present writer is aware, shaft-sinking has not hitherto been treated from the British standpoint in a work devoted to the subject alone.

It seemed, therefore, that a distinct want might be fulfilled by the contribution to mining literature of a work on the sinking and lining of shafts, which, while describing the methods ordinarily adopted, should also offer some account of such modern systems as are used under what may be regarded as exceptionable circumstances.

It has been the endeavour of the author to frame this volume on lines similar to those followed in the construction of Volume I.—namely, to so combine theory with practice that the work may meet the wants both of the mining student and of the mining engineer

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—that it may be used both as a text-book and work of reference.

Many of the figures have been specially drawn, but use has also been made of existing illustrations; and this opportunity is taken of thanking the various authors, manufacturers, and institutions for their courtesy in permitting this. The sources from which the illustrations and other borrowed matter have been derived are acknowledged in the text of the work.

Grateful acknowledgment is also made of the kindness of Messrs. A. M. Lamb and G. Poole in reading through the proof sheets; and to Mr. H. Scott the author is indebted for important particulars relative to the sinking-drum process as adopted at a winning in Northumberland.

R. A. S. REDMAYNE.

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MODERN PRACTICE IN MINING

CHAPTER I

INTRODUCTION: POSITION, SHAPE, SIZE, AND NUMBER OF SHAFTS—LEGAL RESTRICTIONS

Introduction.—The sinking of shafts for the working of coal, stone, or metalliferous ores undoubtedly constitutes one of the most important branches of mining engineering, and in those cases where loose ground, running sands, or heavily watered strata have to be penetrated, is often an extremely difficult and costly operation. Regarding the subject from the coal-mining point of view, the great and increasing depth to which shafts have to be sunk, not only in the United Kingdom, but on the Continent, owing to the gradual exhaustion of the shallow supplies of coal, together with larger size of the shafts, and the enormous cost of some of the undertakings, render the subject one of the greatest interest to the colliery owner, mining engineer, and sinking contractor.

Up to the time of the invention of the atmospheric engine, in 1810, by Thomas Newcomen, mine shafts were much limited in point of depth, by reason of the difficulties of extracting the water. Sixty fathoms (360 feet) was about the maximum depth attained by colliery shafts in Great Britain, their diameter being seldom,

if ever, more than 7 or 8 feet, and the area of coal worked to one shaft rarely exceeding a radius of 200 feet, with the shaft as centre. Fifty years later, amidst great rejoicing, Walker Colliery, on the banks of the Tyne, was sunk to the Main Coal seam, at a depth of 100 fathoms (600 feet) from the surface, a medal being struck to commemorate the event. It will be realised, therefore, that at this time the operation of opening out a colliery was not—even with the limited engineering appliances at the command of the industry—a very hazardous and costly undertaking. But it soon became so; and as early as 1829 Mr. John Buddle (sometimes called the father of the northern coal trade), when giving evidence before the House of Lords, declared that the cost of sinking was frequently from £10,000 to £15,000; and in 1857 Mr. J. T. Taylor stated before a select committee on the rating of mines, that at Haswell Colliery, in the county of Durham, £40,000 was expended in contending with a quick-sand, and the shaft had ultimately to be abandoned. At Murton Colliery, in the same county, over £300,000 was spent in sinking, the quantity of water pumped whilst passing through the Permian rocks overlying the Coal-Measures amounting on an average to 9306 gallons per minute from a depth of 540 feet; the ultimate depth reached (in 1843) by these shafts being 1488 feet. In the aggregate, 10,000 horse-power was employed to raise the water. It is a notable fact that this, one of the most difficult sinkings on record, was accomplished by, what may be termed, ordinary sinking methods.

A still more costly sinking was recently carried out in Belgium,[1] where the putting down and lining of

[1] "Le Bassin Nouiller du Nord de la Belgique, Coupe des Sondages Campine," *Annales des Mines de Belgique*, 1906, vol. xi. p. 361.

two pits through 1968½ feet of water-bearing strata cost £480,000, and a further 338 feet in Coal-Measures £4000 more, or a total cost of £484,000 for the two shafts—equivalent to nearly £105 per foot sunk and lined; the full cost in sinking and equipping the colliery amounting to £694,200.

With the improved appliances and modern methods now available it is possible to sink shafts to great depths; and some of the deepest colliery shafts in the world may be mentioned.

TABLE I.—*Some Deep Shafts*

Belgium	Providence Shaft (No. 18 Pit Machienne Collieries)[1]	3937	ft.	to bottom of sump.	
England	Ashton Moss, Lancashire	2880	„	„	„
	Florence Colliery, North Staffordshire	2670	„	„	„
	Rosebridge Colliery, Wigan	2442	„	„	„
	Harris' Deep Navigation, South Wales	2280	„	„	„
United States of America	Potsville Shaft (disused) of the Philadelphia and Reading Coal & Iron Co.	2000	„	„	„

But deep as some coal-mine shafts are, they are exceeded in this respect by several metalliferous mines. For instance, the No. 3 shaft of the Tamarack Copper Mine in Northern Michigan, the bottom of which is 5000 feet vertically from the surface, is the deepest mine in the world.

In respect to shaft-sinking by hand, it is doubtful whether the continental engineers can compete with the British. Many of the most difficult sinkings on the Continent during the 'sixties and 'seventies were carried out by English contractors. But of late years

[1] The author visited this mine in the spring of last year (1908), and noted that the crush at the lowest winding level, 3707 feet, was very great.

special methods—brought into operation through the difficult nature of the ground to be penetrated—have been devised by continental engineers and contractors, which meet such special requirements as are becoming more and more common, and several very important collieries have been sunk in Great Britain with marked success by these methods, accounts of which will be found in the pages of this book.

Uses of Shafts.—Colliery shafts may fulfil any of the following functions. They are used either for—

(*a*) The purpose of extraction of mineral.
(*b*) Lowering and raising of persons.
(*c*) Ventilation.
(*d*) Extraction of water (pumping).
(*e*) Transmission of power from the surface to the underground workings.

For the purpose of efficient ventilation, there must be two shafts at least—one a downcast for the *intake* air, and an upcast for the *return* or vitiated air. Both these shafts may be, and frequently are, used for the winding of men and coal, but pumping is most frequently restricted to the downcast. In many large collieries a separate shaft is set aside for the conveyance of the workpeople—a fact making for economy, as it allows of the uninterrupted winding of coal in the drawing shafts, and is not unattended with safety considerations.

Preliminary Considerations.—Having accurately proved by topographical and geological surveys and by boring, the value, number, inclination, and extent of the coal seams, and the character of the ground to be penetrated, the mining engineer will have to determine the position, size, depth, and number of the shafts to be sunk, with a view to developing the tract of coal he has to exploit. It may be that the seams

outcrop on the property, and can be worked by levels driven in the same, or, if the country is hilly and the seam highly inclined, by cross-measure drifts; but even in these cases it is found convenient, where the workings have advanced some distance, to sink a shaft or shafts.

Having then prepared a detailed plan of the area to be mined, and, if possible, of the adjacent tracts, showing the surface contours and such additional physical features as water-courses, lakes, and such artificial features as railway lines, canals, reservoirs, bridges, and dwellings; and having marked on this plan the position of the bore-holes, with the data obtained therefrom, as well as the course of any large faults or igneous intrusions, the first problem that confronts the mining engineer is the selection of the position of the shafts. Other things being equal, and if the tract to be exploited be not unduly extensive, the proper position in which to sink the shafts would be in the centre of the property, as being the best situation for developing the whole area; but circumstances do not always allow of this simple solution of the question.

Position of Shafts.—The conditions chiefly determining the position of the shafts are—

(*a*) The contour of the surface.

(*b*) Proximity to railways or canals.

(*c*) Character and inclination of the strata to be penetrated.

(*d*) Geological disturbances.

(*e*) The proposed method of working the coal.

(*a*) The effect of the surface contour is obvious. It would be absurd to sink from the top of a high hill to seams of coal lying at a depth below the valley, and yet it may be advisable, in order to avoid flooding, on account of the exigencies of area for surface

work, or to obtain a sufficient gradient for railway branches or height for screening arrangements, to locate the shafts at some distance up the hill. A prominent instance of the controlling effect of contour on the position of shafts is the South Wales coalfield, where, owing to the field being traversed by deep valleys, caused by denudation, the large collieries working the lower and steam coal seams, are situate in the valleys, though some small landsale mines working the upper and outcropping seams by means of adits or day-levels, are situated on the mountain sides.

If the site of the colliery is far from any existing means of transport, and it is necessary to construct a railway, the contour and other physical features of the country may have a very important bearing in the solution of the problem.

(*b*) If other conditions allow of it, a considerable capital expenditure may sometimes be saved by sinking the drawing shaft or shafts in close proximity to the means of transit—railway or canal, or both.

(*c*) The character and inclination of the strata to be penetrated also have a very important bearing on the question of position, as well as on that of cost, the latter sometimes governing the former. The geological survey and borings will have enabled the mining engineer to locate the position of any overlying deposits of loose ground, sands, gravels, or boulder clay, which he will, if possible, avoid sinking through. The strata constituting the Coal-Measures of Great Britain, and, indeed, of many other parts of the world, do not vary greatly in one mining district as compared with another, consisting as they do of alternations of sandstones, shales, fireclays, and coals, a rough estimate showing the average to be in the proportion of 20 of sandstone to 12 of shale

and 1 of coal, but they do vary in point of the thickness of the different beds, and considerably so in respect to the amount of water contained in the strata. The collecting area of the outcropping bed, and, as remarked on page 115 of "Boring for Coal" (vol. i.), the piezometrical level of a "water sheet," have a most important bearing in this respect. If, too, there occur from the surface downwards, a series of beds of "open" rock (*e.g.* sandstone or a limestone with fissures), uninterrupted by the interposition of an impervious stratum (*e.g.* argillaceous shale), on the approach to a bed of the latter description, the strata are very certain to contain a considerable quantity of water (feeders).

In Great Britain the most difficult and costly winnings have been those sunk to the Coal-Measures through overlying Permian strata (the east coast of Durham, South and West Staffordshire) (see pages 243, 253, 258), where vast quantities of water have had to be contended with, both in the magnesian limestone itself (the Middle Permian of the east coast of Durham), but most particularly in the underlying sands or Lower Permian (Durham), and in the "Red Rocks" or sandstones of the so-called Permian of the Midlands (South Staffordshire). Sinkings through these strata are mostly of recent date, and are likely to be more frequent in the future than in the past, owing to the gradual exhaustion of the "exposed" area of the British coalfields necessitating the more extensive exploitation of the "hidden" fields.

On the Continent some of the most hazardous and costly sinkings have been those made through the Tertiary and the Cretaceous beds overlying the Coal-Measures. The difficulties encountered in putting down some of the latter of these undertakings led to the application

of the Kind-Chaudron process, in the first instance, and later on, to other special methods, such as the Pattberg and the Congelation processes, described later on in this volume. For instance, the Kent coalfield, where two shafts have recently been in part sunk by the Kind-Chaudron process, underlies Cretaceous rocks (see pages 234, 235, 243).

For the purposes of drainage of workings and underground haulage, if the seams are inclined, the farther "to the dip" that the drawing shafts are sunk the better, but from the point of view of "ventilation" the upcast or ventilating shaft should be sunk "to the rise." The greater the inclination, the more forcible is the argument in favour of this line of procedure, though another factor may enter into the case, namely, that of capital outlay, for difference in point of cost as between sinking the drawing (and pumping) shaft at the extreme dip and near the "rise" end of a property may be enormous, so much so that it may be deemed advisable to save this, even though it be at the expense of an increased eventual working cost, caused by having to pump the water from the face to the shaft bottom and the heavier haulage. When all is said and done, it mainly resolves itself into a financial question, and a balancing of items of capital expenditure and working cost.

(*d*) The shafts should be placed so as to be clear of faults. Sinking on a fault, although the ground may be more easily excavated, is dangerous, in that heavy side-falls may occur, and the undertaking may be rendered hazardous and costly by reason of the line of fault acting as a natural water-course. Anything that tends to a movement of the sides of a shaft is a source of danger also. Not only should the shafts themselves be clear of faults, but should be so placed as to avoid the necessity, when sunk, of driving

cross-measure drifts to "recover" seams lost through faulting, wash-outs, or dykes. Two instances occur to the author's mind in this connection—the one where a dealer in dry-goods, desirous of becoming a colliery owner, spent a small fortune in sinking two shafts without a preliminary boring, and penetrated heavily watered strata, only to discover that the seams had been denuded; the other where one of the shafts was sunk on a fault, and judging from the nature of the seams as revealed in the immediately adjoining property —where the principal seam was of fine section and quality—it might have been supposed that similar conditions prevailed in the new area; but on reaching it the seam was found to have thinned out to an unprofitable section. It was many years before this venture returned profits, and then only when sinkings had been carried out farther afield.

When there are two shafts, they must, according to the British Coal Mines Regulation Act, be not nearer together than 15 yards (see Legal Restrictions, p. 19).

Other things allowing of it, the shafts should not be located far apart from each other, for by sinking them near together, not only are the points of delivery of material and despatch of output concentrated—a feature of importance in the future of the undertaking—but it is possible to use plant and material in common when carrying out the work of sinking itself. Concentration makes for saving in capital expenditure, and, eventually, a low working cost.

(*e*) *The proposed Method of Working the Coal.*—It is usually considered preferable, for reasons already advanced, to work the coal, or, at any rate, the greater proportion of the area, "to the rise"; but if the field be an extensive one, it may be advisable to have the

shafts some distance to the rise, and work the area to both rise and dip. Some engineers adopt the area proportion of 4 of rise to 1 of dip workings—the object being to obtain a greater extent of face, and consequent enhancement of output.

If the inclination of the seams is very great, it will, in all probability, be deemed advantageous to put

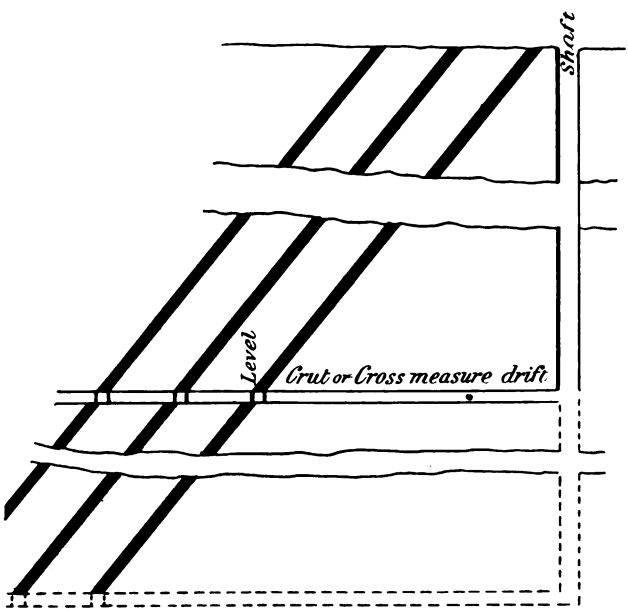

FIG. 1.—Position of Shaft in relation to highly inclined Seams of Coal.

down the shafts to the rise, and cross-cut (cross-measure drift, or crut) to the seam or seams, and work to the rise (see Fig. 1), as with the system of "rearer workings" in North Staffordshire, where the seam is "recovered," as it is called, in breadths of 120 yards, by "crutting," *i.e.* driving, stone-drifts from the shaft to the seam in which the levels are to be driven (see "Methods of Working," vol. iii.).

The Number of Shafts.—The determining factors in respect of the number of the shafts to be sunk on a given coal-mining property may be included under the following heads:—

(*a*) Area of the property (take, royalty, concession).

(*b*) Proposed output.

(*c*) Depth of the coal from the surface.

(*d*) System of ventilation and pumping to be adopted.

(*e*) Legal restrictions.

(*a*), (*b*), and (*c*). The area of the property, the output of coal which it is desired to raise, and the depth at which it lies from the surface, are features in the problem so bound up one with another, that it is best to consider them in connection with each other. In a district like the "exposed" portion of the South Staffordshire coalfield, for instance, great numbers of shafts are to be seen within a comparatively small area, due to two facts: the shallow depth at which the coal occurs below the surface, and the great thickness of the so-called "Thick" or "Ten-Yard Seam." The cost of a sinking is small, and the area worked by one concern restricted.

Speaking generally, the greater the depth the more extended should be the area of the property to be exploited—though this is truer of very great than of more moderate depths. In order to allow of the redemption of, and a fair return or interest on, the huge capital expenditure which has been embarked in undertakings, the output from these larger concerns is usually much greater than from those of shallow depth.

(*d*) *Ventilation and Pumping.*—Where the question of depth does not enter into consideration, or at any rate not to a commanding degree, when the exigencies of ventilation require it, additional downcast and upcast shafts will be sunk. But where the depth

is great, relief, in this respect, is sought for in the increased size of the two or three shafts with which the property is won, as this can be obtained at a lower expenditure than by a separate winning.

The area of coal worked to one winning—and by winning in this respect is meant one *group* of shafts, usually two or three—is frequently over one thousand acres.

The engineer should have so studied the natural and geological conditions of the property he is about to develop, have laid out the scheme of the underground working, and weighed the questions of trade and prospective developments, that in the years to come it should not be found necessary to sink additional shafts, when such would have been unnecessary had he exercised proper foresight and skill when opening out the property.

(*e*) *The Legal Restrictions* bearing on shafts are set forth on pages 19 and 20; by these, there must, under ordinary circumstances, be at least two shafts or outlets to every mine.

The Shape and Size of Shafts.—In the coal-mining districts of the Continent of Europe various forms of shafts are adopted—rectangular, elliptical, polygonal, and circular; perhaps the most common shapes being the rectangular and circular, though the elliptical[1] form is far from rare. In America and the British Colonies the shafts are most frequently rectangular, and in Scotland also, though latterly, especially in the case of the deeper sinkings, the tendency has

[1] Herr Baumann says (*Zeitschrift des Vereines Deutscher Ingenieure*, 1884, pp. 296–298) that in order to economise space, most of the earlier German shafts were made rectangular, but that eventually the circular form was found both easier and cheaper to sink as well as more suitable for the application of metal tubbing.

been to make them circular. In England and Wales the circular form has been, and is almost exclusively, adopted.[1]

There is less waste of space with the rectangular than with the other shapes, whereas this is greatest in the case of the circular form (see Fig. 2), but the latter has the advantage of being best fitted to resist side pressure. Where stone or clay, such as can be manufactured into suitable bricks, is easy of access, the circular form lends itself most readily to the nature of these materials; on the contrary, where wood is abundant, provided the nature of the ground to be sunk through allows of it, the rectangular form may be deemed the most suitable. Where the shafts are deep and the workings likely to be extensive, and the ventilation requirements will occasion a comparatively high velocity of air current in the shafts, the circular shaft has the advantage over the rectangular one, in that it offers less rubbing surface, and hence less friction, to the flowing air. Thus a circle, the diameter of which is 1, has a circumference of 3·1416, whereas a square, the width of which is 1, has a perimeter of 4.

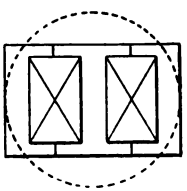

FIG. 2. — Circular and Rectangular Shafts compared in respect of Waste of Space.

Presumably shafts are sunk oblong in preference to circular with the object of taking out as little ground as possible, but if this is so, then for the same size of cage there is, in the former case, the added difficulty of insufficiency of space to fulfil ventilating re-

[1] One of the shafts of North Elswick Colliery (sunk in 1845), near Newcastle-upon-Tyne, is oval in form. One of the shafts also at the Waunfawr Colliery, Risca, South Wales—the upcast or furnace pit—is oval-shaped, being 16 feet by 10 feet. At Wemyss Collieries, in Fifeshire, there is also a large modern elliptical shaft.

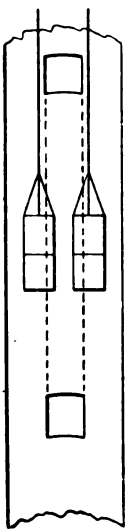

FIG. 3.—Arrangement to secure effective air-passage at "meetings."

quirements when the cages are at meetings, though this may be overcome by making a holing above and below meetings, and connecting them in the manner shown in Fig. 3.[1]

According to Mr. Coulson, an oblong shaft of the same area as one 18 feet in diameter, should be about 24 feet long by 10 feet wide.

Mr. A. E. Pettit[2] has tabulated the comparative results in respect to circular and rectangular shafts, taking for this purpose comparative sections of two shafts on the Rand—the Langlaagte Royal and the New Primrose. These are both circular shafts, and he compares them with rectangular shafts of the same useful area. See Fig. 4.

TABLE II.—*Comparative Useful Areas of different Forms of Shafts (Transvaal)*

Shaft.	Area of Shaft.	Area of Rectangular Shaft of equal *useful* Area.	Saving in Area Rectangular Shaft.	Percentage of Area useless in Circular Shaft.
	Sq. ft.	Sq. ft.	Sq. ft.	
Langlaagte Royal	176·7	113·66	63·04	35·7 per cent.
		Ft. In. Ft. In. 20 8 × 5 6		
New Primrose . .	95·03	Sq. ft. 54·08	40·95	44·2 per cent.
		Ft. In. Ft. In. 9 10 × 5 6		

Mr. Coulson's experience in the matter connected with the sinking of shafts is so extensive that the

[1] Mr. F. Coulson, who is justly reputed one of the foremost sinking contractors in the United Kingdom, says (*Trans. Inst. M.E.*, vol. viii. p. 17): "This consideration is, in fact, so important, that in many cases it is deemed desirable to sink the staple for a height of some 120 feet."

[2] "Sinking, Development, and Underground Equipment of Deep-level Shafts on the Rand," by A. E. Pettit, *Trans. Inst. M.M.*, vol. xv. pp. 333–366.

author does not hesitate to reproduce the reasons he advances against oblong shafts as compared with the circular form.[1]

(*a*) "The cost of sinking is enhanced, owing to the difficulty of squaring out corners.

(*b*) "The cost of lining is more. An oblong shaft lined with timber costs £2, 5s. per foot; a round shaft lined with bricks at 20s. per 1000 costs £1, 4s. 2d. per foot.

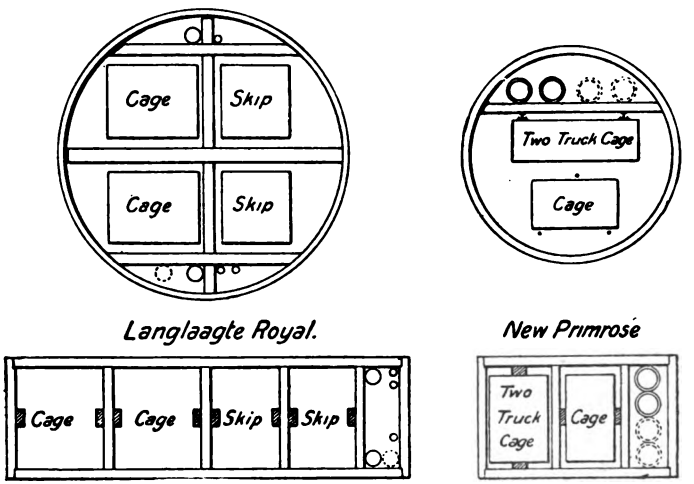

FIG. 4.—Comparative Sections of Circular and Rectangular Shafts.

(*c*) "It is more difficult to shut off water in a square shaft.

(*d*) "The difficulty of placing the shaft in the most suitable situation, having regard to surface and underground arrangements, the position of railway sidings, and other considerations. The author [Mr. Coulson] is of opinion that it is desirable, not to say essential, that the greatest length of an oblong shaft should

[1] "Sinking with Rock Drills," by F. Coulson, *Trans. Inst. M.E.*, vol. viii. pp. 17, 18.

be across the cleat of the stone, so that the long side may be in the position most easily supported.

(*e*) "When sinking through the leader of a trouble running . . . across the narrow width of the shaft, the danger to the men and the cost of securing the sides of the shaft is enormously increased in the case of an oblong shaft."

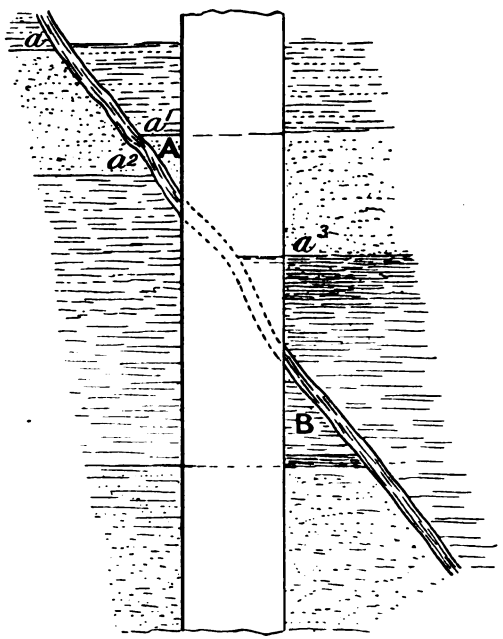

FIG. 5.—Shaft sunk on a Fault (trouble).

Mr. Coulson illustrates this case by a figure for which Fig. 5 will suffice equally well. He points out that a mass of stone in the position shown at A will be very liable to fall, and that the stone at B will be very difficult to support.

(*f*) "The timber lining will not last so long as brick-work, and, seeing that the shaft is the one road into the mine through which all the men must pass in going and coming from their work, it is desirable that it should be made as safe as possible by being securely lined throughout. Some of the rock met with near the surface may be left unlined, but after a few years such places require frequent attention."

With the exception of the first part of the argument as to the difficulty of placing the shaft (see *d*), the bearing of which the present writer cannot quite follow, the above objections to adopting the oblong-shaped shaft in preference to the round seem unanswerable.

The object of the elliptical and oval shape is to combine some of the advantages of the circular and rectangular, viz. strength and economy of space, but the difficulty of keeping a deep shaft of this shape plumb, and the obstacles presented to effective walling or tubbing, render it an undesirable form.

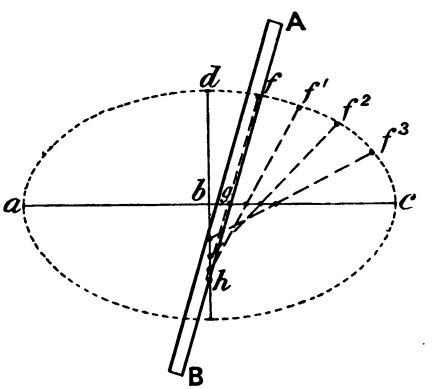

FIG. 6.—Method of Laying Out an Elliptical Shaft.

"Laying out" an Elliptical Shaft.—The following is a method of "laying out" an elliptical shaft:—At the spot where the shaft is to be sunk, draw two lines at right angles to each other (Fig. 6); one of these being the major, the other the minor axis of the ellipse.

From the point at which they cut, measure half the lengths of the two axes, then if the major axis is 16 feet and the minor axis 10 feet, make the length *ab bc* each 8 feet and *bd* 5 feet each. On a straight-edge make *fg* equal to half the length of the minor axis and *fh* equal to half the major axis. Then mark off the points f^1, f^2, f^3 by moving the point *g* along the major axis and *h* along the minor axis.

It may not be out of place to remind the reader, who may have to estimate sinking and walling costs, of the following facts and figures:—

1. To estimate the quantity of material in cubic feet to be extracted from a circular shaft, square the diameter of the outer circle in feet, and multiply the result by 0·7854 and by the depth in feet. To arrive at the weight in tons, multiply the above result by the specific gravity of the substance, and by 62·5 (the weight of a cubic foot of water in lbs.), dividing the result by 2240.

2. To estimate the same in the case of an elliptical shaft, multiply half the major by half the minor axis, and the result by 3·1416, which gives the area, and proceed as above.

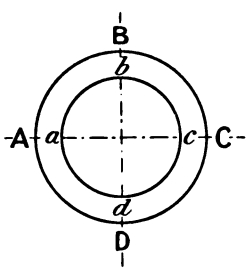

FIG. 7.

3. To estimate the walling contents of a circular shaft, multiply the difference of the areas of the greater and lesser circles by the depth. Thus in Fig. 7 the area of the space included between the circles ABCD and *abcd* must be multiplied by the depth.

4. Proceed in a similar manner in the case of an elliptical shaft.

The modern tendency is towards an increase in the size of the shafts. Circular shafts, in which two

cages are to work, should not be less than 9 feet in diameter, and are sometimes as much as 21 feet.[1] Scotch rectangular shafts, with single cages, vary from 12 to 16 feet long by 5½ to 6 feet wide, and, with double cages, from 18 to 24 feet long to 6 to 7 feet wide. But the size will of course depend on the purposes which they have to serve—whether for winding, pumping, and conveyance of underground haulage ropes, or whether steam pipes are carried in them, and whether these operations are restricted to one or more shafts, but principally will it depend on the size of the cage—whether a large or small output is to be raised—the number of shafts to be sunk, and the coal area to be worked.

Legal Restrictions

British.—The Coal Mines Regulation Act of 1887 (which consolidates, with amendments, the Coal Mines Acts of 1872 and 1886, and the Stratified Ironstone Mines Act of 1881) stipulates in respect of shafts, that unless the case is exempted by a Secretary of State "by reason of the thinness of the seams or other exigencies affecting that mine or class of mine" (Sec. 16, (1.) (*a*) (*b*) (*c*)), that (Sections 16, 17, 18) no person shall be employed in a mine unless there are two shafts or outlets therefrom, with which every working seam must be connected, and such shafts or outlets must not at any point be nearer to each other than 15 yards, and shall have a communication between them of not less than 4 feet high by 4 feet wide. But the provisions do not apply—

[1] Although the tendency is towards an increased diameter of shafts, it should be borne in mind that in the case of water-bearing strata, a large diameter means greater thickness of tubbing and increased expenditure.

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1. "In the case of a new mine being opened"—
   (*a*) "To any working for the purpose of making a communication between two or more shafts," or—
   (*b*) "To any working for the purpose of searching for or proving minerals;

"so long as not more than twenty persons are employed below ground at any one time in the whole of the different seams in connection with a single shaft or outlet"; nor

2. "To any proved mine so long as it is exempted by order of a Secretary of State," on the grounds that the quantity of mineral is not sufficient to pay for the cost of sinking a second shaft, and where the workings have reached the boundary, so long as not more than twenty persons are employed below ground at any one time. But these last two exceptions hardly apply at the present time, seeing that by "any proved mine" is meant a mine existing at the date when the Act came into force.

3. To any Mine—
   (*a*) "While a shaft is being sunk, or an outlet being made," or
   (*b*) One of the shafts or outlets of which has become, by reason of some accident, unavailable for the use of the persons employed in the mine; so long as the mine is exempted by order of a Secretary of State. (Sec. 18.)

The top of every abandoned shaft, or of any shaft which is for the time being out of use, or used only as an air shaft, has to be securely fenced (Sec. 37 and Sec. 49, General Rule 18).

CHAPTER II

METHODS OF SINKING—PRELIMINARY OPERATIONS; TOOLS AND APPLIANCES USED IN SINKING SHAFTS; SINKING SHALLOW SHAFTS; HEADGEAR AND WINDING ARRANGEMENTS; ROPES AND KIBBLES

The various Methods of Sinking Shafts.—The methods of sinking shafts may be classed as follows:—

Method of sinking.	*When adopted.*
1. The ordinary method of sinking by hand at the bottom of the shaft. Drilling and blasting out the stone. Encasing the shaft with temporary wood cribs and backing deals, to be succeeded by brick or stone walling, the bottom of the shaft being drained of water by means of water kibbles.	When shafts have to be sunk through ordinary and fairly dry strata.
2. Sinking as above, the water being drawn or forced to the surface by means of pumping appliances, usually hung in the shaft by means of chains. When large feeders of water are being given off, the shaft is lined by "coffering" or cast-iron tubbing.	When sinking shafts through water-bearing strata.
3. *Piling.*—Commencing the pit of large diameter and driving down wooden piles, tier within tier, until the stone-head is reached, or by using interlocking channel girder piles, or Walker's method of forcing down steel piles carrying tubbing and guided by an	When sinking through thick surface deposits of sand, gravel, or clay.

Method of sinking.	*When adopted.*
advance guide-ring. The two latter methods not necessitating the commencement of the shaft at an exceedingly large diameter.	
4. *Haase's System*, consisting in driving down tubes side by side so as to form the lining of the intended shaft.	When sinking through thick surface deposits of sand and gravel.
5. *The Sinking-Drum Method*, by which a "drop shaft" of cast iron rings bolted together to form a cylinder is lowered from the surface as the sinking proceeds. The sinking being performed by the ordinary method at the bottom of the shaft or by means of a "grabber."	When sinking through surface loose water-bearing strata.
6. *The Sack-Borer Process*, by which the shaft is bored out and the débris is caught in sacks which are raised by the engine independently of the borer and boring rods.	When sinking through surface loose water-bearing strata.
7. *The Pneumatic System* of M. Triger and others, by which a caisson, in which the sinkers work, is lowered as the sinking proceeds, the water being prevented from entering the same owing to the greater pressure of the compressed air within the caisson.	When sinking through surface loose water-bearing strata limited to a depth of 120 feet.
8. *The Honigmann System* of sinking and lining shafts, consisting in boring out the shaft and applying muddy water under high pressure to sustain the sides of the same and raise the débris.	When sinking through surface sands, gravels, or clays.
9. *The Pattberg System*, which is somewhat similar to the Kind-Chaudron, except that whereas in the latter, the débris is raised	When sinking through firm strata containing large quantities of water which cannot be coped with by pumping.

Method of sinking.	*When adopted.*
to the surface in buckets, in the former it is forced up by means of a current of compressed air.	
10. *Cementation Process*, by which the beds to be penetrated are first consolidated by the injection of liquid cement, and then sunk through by the ordinary method.	When sinking through thick surface deposits of sand and gravel, or when penetrating rocks which are heavily fissured and contain water.
11. *Kind-Chaudron Process* of sinking by boring out the shaft from the surface, lowering down complete rings of metal tubbing, and afterwards pumping out the pit.	When sinking through firm strata containing large quantities of water which cannot be coped with by pumping.
12. *The Hydraulic-Ram Boring Process*, in which the force necessary to work the borer is applied by hydraulic shock to a series of cutters or chisels at the bottom of the shaft.	When sinking through firm strata containing large quantities of water which cannot be coped with by pumping.
13. *Freezing Process*, by which the water-bearing stratum is frozen in the vicinity of the shaft, which is sunk by hand and tubbed whilst the ground is in the congealed state.	When penetrating loose water-bearing strata either at the surface or when occurring at some depth therefrom.

In the succeeding pages these methods will be considered in the order in which they are mentioned above.

Sinking and Lining of Circular Shafts

Preliminary Considerations and Operations.—Frequently, when shafts are to be sunk for the purpose of opening out an entirely new colliery, the site is too far removed from a town or village in which the sinkers can be conveniently housed. It may be necessary,

therefore, to erect a few cottages in the immediate neighbourhood of the undertaking, which, as they can afterwards be used as miners' dwellings, may be substantially built of brick or stone; such temporary erections as a sinker's cabin, smithy, store-house, and offices may be conveniently constructed of wood and corrugated iron. It will be necessary also to have a magazine for explosives not far distant, which may be either built of brick or stone, lined inside and floored with wood. The end of an egg-ended boiler, wood-lined inside and set on end on a brick or stone foundation (wood-floored), makes a good magazine.

Rapidity of execution is often essential to the success of a sinking undertaking, especially if the shafts have to penetrate shifting ground or heavily watered strata. It will be found advisable, therefore, to have as much of the necessary material as possible on the spot at the commencement of active operations, so that there may be no cessation in sinking; the tools consisting of picks (stone hacks), sinking shovels, stone-blasting gear, rock-boring machines; the other appliances, chiefly kibbles, with either bellying sides, so as to shear off from any projections, or provided with guides, the covering arrangement for the top of the shaft and the landing of the kibbles, a winding engine, and water kibbles or pumps. The downcast and upcast shafts should be sunk simultaneously in order that there may be no unnecessary delay in opening out the seam when it has been reached; and it will be found advisable, if the conditions of the property allow of it, to sink the two shafts fairly near together, so that the engines may be supplied with steam from the same range of boilers.

Prospecting Shafts and Shallow Sinkings—Sinking Winches.—When the seams of coal exist

at a shallow depth from the surface, shafts are frequently sunk for prospecting purposes as being a more thorough and satisfactory way than by boring—though a more costly operation—of proving the value and of determining the thickness, depth, and inclination of the coal beds. In such cases the shaft will in all probability be a rectangular one, the sides being supported by timber, and, possibly, it will not be used as the permanent shaft, should the coal be found to be worth working.

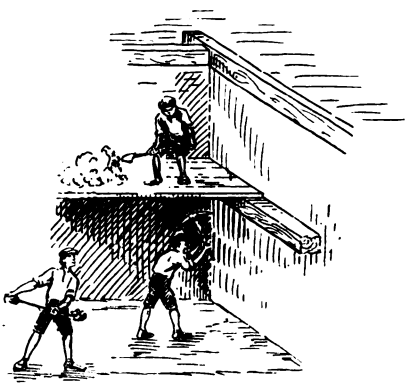

FIG. 8—Sinking a shallow Shaft.

In the earlier stages of sinking shafts, or during the entire sinking if it be a very shallow one, the excavated material may be handled in the manner indicated in Fig. 8—that is, casting it from stage to stage, erected temporarily in the shaft. But it would not pay to go to the expense and trouble of inserting stages if eventually it is intended to hoist the débris by means of a jack-roll.

In continuing the sinking of such shafts, a jack-roll, winch, or mining windlass will suffice for raising and lowering the workers, tools, and material, and hoisting up the débris; and, in the earlier stages of sinking deep shafts, *i.e.* when sinking to the stone-head, jack-rolls are also sometimes used; though, if the shaft is to be a deep one, it will be as well to establish the sinking engines at the outset.

The depth from which it is possible to wind with the ordinary jack-roll is limited by the number of coils

of rope which can be wound on the barrel. That this is so can be demonstrated graphically. Winding with a winch may be performed—(1) with a single rope for raising and lowering a kibble wound either once on the barrel of the winch or coil upon coil; (2) a single rope may be employed, as in the Koepe system, and both ends used, one kibble being raised as the other is lowered; (3) two ropes may be used as in Figs. 9, 10, 11, the ropes being fixed to either end of the barrel, in which case Fig. 9 shows the rope *a* about to commence winding up and *b* about to be uncoiled. In Fig. 10 the rope *a* has been coiled up once on the barrel, and *b* is uncoiled to its full extent; or (4) two ropes can be made to commence to coil and uncoil from the middle length of the barrel (Fig. 11).

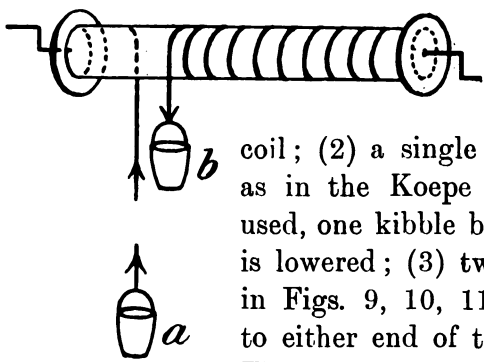

FIG. 9.

Taking then the case (Fig. 11), it can be shown that either rope can be wound only twice, one coil on the other. For if *a* is wound three times on the half of the barrel *ac*, the other half *bd* is of course bare of rope. *a* unwinds towards *c*, *b* coils up towards *d*, so eventually *a* is unwound as far as *c* to the extent of one series of coils, and *b* wound up to *d* to the extent of one series of coils. Proceeding with the winding, at mid-distance *a* is unwound to the extent of two series of coils—that is to say, for a distance *ac* there

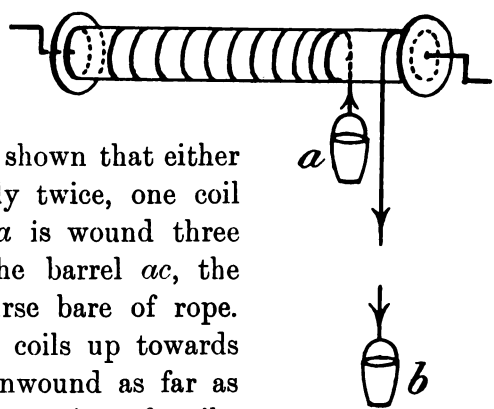

FIG. 10.

exists but one series of coils, and over the length *bd* there are two series of coils (Fig. 12), and were further winding to be proceeded with, the coils of the rope

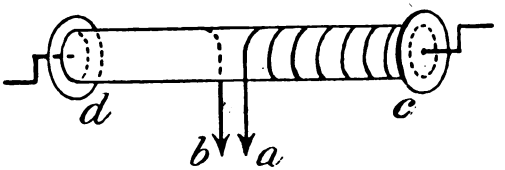

FIG. 11.

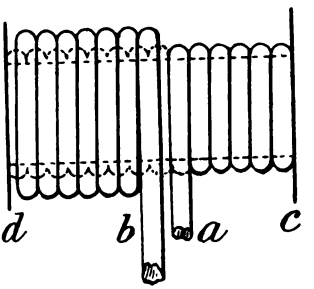

FIG. 12.

b would topple over. So taking case (3) as the most practicable, the depth is limited by the number of coils which can be wound on the barrel, and if

D = the diameter of the barrel,
l = the length of the barrel,
d = the diameter of the rope,

then $\frac{l}{d}$ = the number of coils which is possible, and D + *d* = the virtual diameter of the drum.[1]

$\pi \times (D + d)$ = the length of each coil;

∴ the greatest depth from which it is possible to wind with the winch

$$= \frac{l}{d} \times \pi (D + d)$$

$$= l \times \pi \frac{(D + d)}{d}.$$

If the diameter of the barrel is increased, the proportion between the leverage of the arm and the load is diminished, and if the length of the barrel is increased the size of the shaft has to be increased likewise. If,

[1] Thus in Fig. 13 *a'a* = the diameter of the rope, *abc* = the circumference of the barrel, or the inner circumference of the rope coil, and *a' b' c'* = the outer circumference of the rope coil. Hence, in estimating the length of each coil, the middle of the rope is taken as being the average of the length of the inner and outer side, namely that represented by the dotted line.

therefore, an increased length of wind is sought, the drum or barrel of the windlass must be divided into two halves by means of a collar in the middle, and each half supplied with a separate rope which can be wound to overlap; but this is not a very satisfactory method.

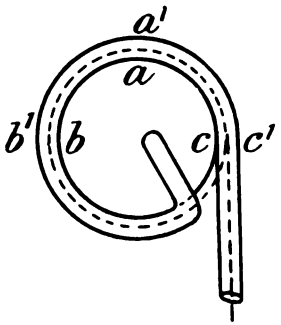

FIG. 13.

Mr. M. G. Percy Ashmore[1] has suggested an admirable form of mining windlass (Fig. 14) using a hempen rope, which overcomes the difficulty, and which is in reality an application of the Koepe system of winding. The rope makes half a turn round the drum, being protected from slipping by means of twelve M-shaped pieces of $\frac{5}{8}$ in. round iron placed round the

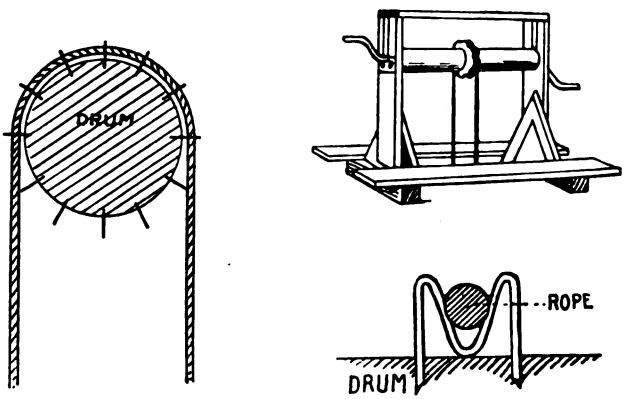

FIG. 14.—An improved form of Mining Windlass.

drum centre. For this appliance it is justly claimed that less rope is used, and there is the further advantage that the kibbles travel in the middle of the shaft.

Where labour is cheap and machinery costly, often

[1] *Trans. Inst. Mining and Metallurgy*, vol. xii. pp. 229–231.

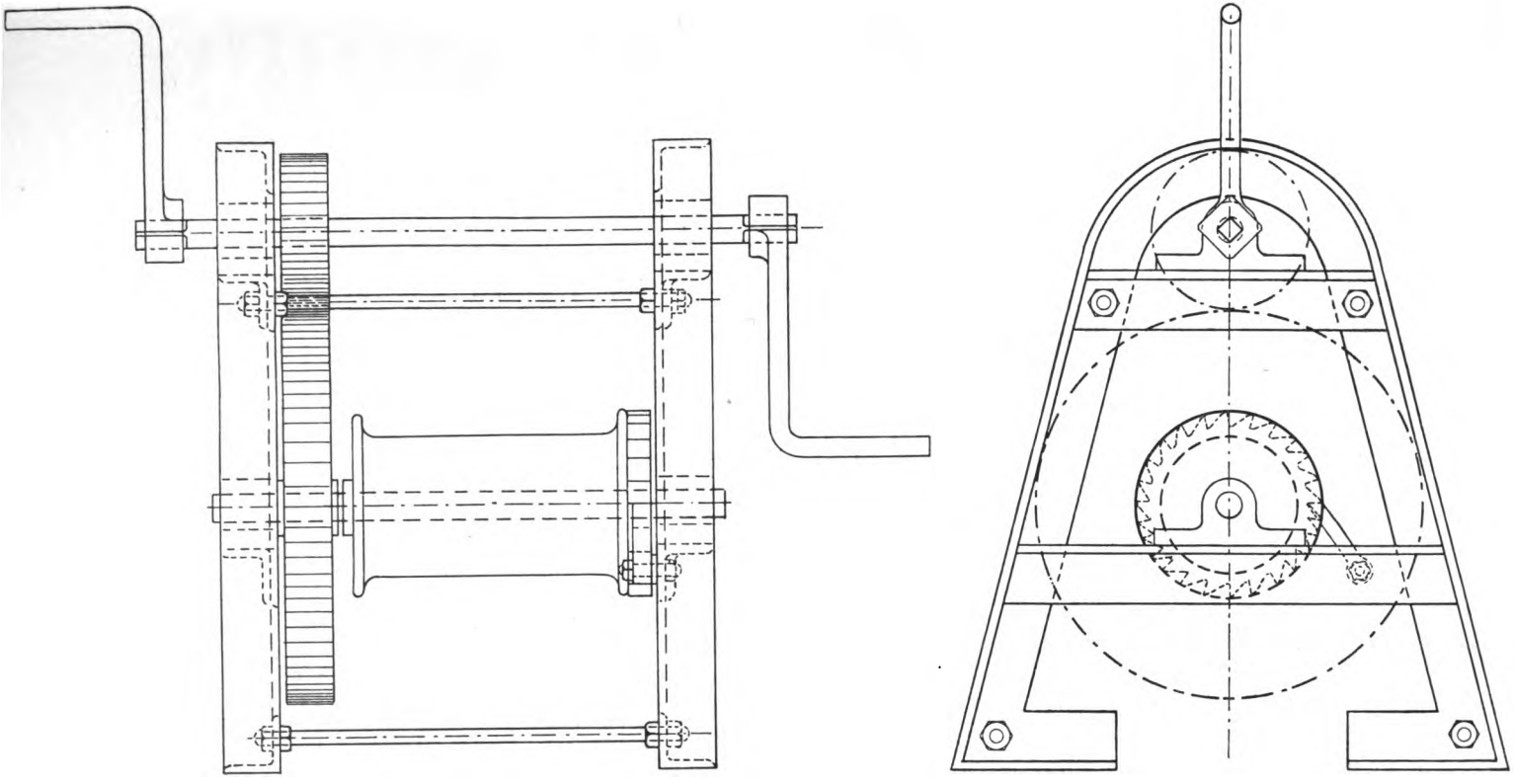

FIG. 15.—Small Hand-winch for Use in Sinking Pits. (Messrs. J. Cook, Sons & Co., Ltd.)

a parallel case, jack-rolls are in some cases used for winding to a depth up to 600 feet. Usually, however, they are restricted to prospecting purposes and applied to depths up to about 120 feet. In the earlier stages of sinking, whilst the erection of the temporary headgear is being proceeded with, and so long as the depth is shallow, it will in all probability be deemed advisable to use a small hand-winch or mining windlass for lowering and raising men and material. Such a windlass is shown in Fig. 15.

Horse-Power Winding Gear.—Fig. 16 represents a winding gear, worked by horse-power, as supplied by Messrs. Fraser & Chalmers, which is especially adapted for prospecting purposes or winding small quantities of minerals or water from moderate depths, until the mine reaches a point of development necessitating the installation of more powerful and permanent machinery. Such a plant is easily handled, and requires no stone or brick foundations, the frame being bolted down on to timbers embedded in the earth. The drum is provided with a clutch and band brake. The "gallows frame" is of iron tubing, the total weight of the gear, including overhead sheaves, being 2400 lbs., and a total load of 400 lbs. can be lifted by it at a speed of 60 feet per minute, at the ordinary rate of walking of a horse. The plant is applicable to depths up to 300 feet.

Figs. 17, 18, 19 illustrate the details of the surface hoisting arrangements, poppet-head (pulley-frame and shear legs), and horse-whim or gin constructed of wood, used for lowering and raising men, materials, and débris, a crab, also made of wood and worked by horse-power, for lowering and raising the building platform on which those engaged in walling the shaft would stand. These arrangements are such as might be used in sink-

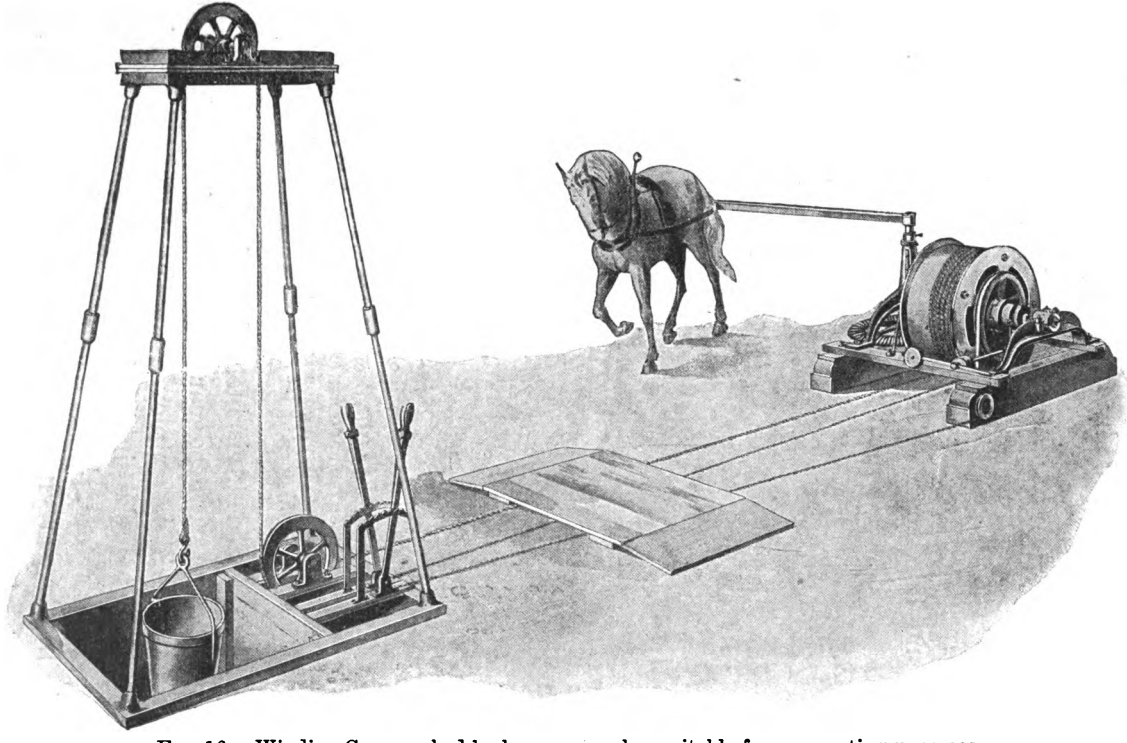

FIG. 16.—Winding Gear worked by horses or mules, suitable for prospecting purposes.

ing and lining a shallow shaft, but one which was too deep to allow of a hand-windlass being used. The figures were sketched by the author from an actual instance some years ago.

Steam Winders and Headgear.—It depends on the depth of the stone-head from the surface as to what arrangements have to be made for raising the débris and lowering and raising the men and tools. It

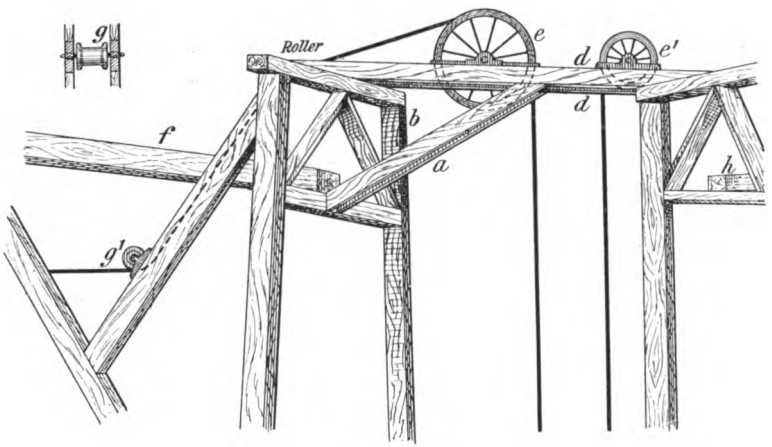

FIG. 17.—Detail of Poppet-Head.

(*a*) Stays; (*b*) Shear Legs; (*d*) Supports for pulley wheels; (*e*) Pulley Wheel for winding men and material; (*e'*) Pulley Wheel for lowering and raising the walling platform; (*f*) Support for gin; (*g* and *g'*) Roller for rope; (*h*) Support for crab.

is usually deemed advisable, when sinking deep shafts, to erect temporary headgear and use engines other than those which will be employed for the permanent raising of the coal when the sinking is accomplished. It may be supposed, therefore, that a temporary headgear, about 25 feet in height, carrying one or more pulley wheels, 10 feet in diameter (see Figs. 20, 21), and an engine consisting of a pair of 14 in. cylinders with 28 in. stroke, using steam at 70 lbs. pressure and working two drums on the

second motion 3 to 1, so arranged that each drum can be separately worked, will suffice for the work of sinking. In all probability a couple of Lancashire boilers will be more than enough to supply the necessary steam unless the pumping is heavy.

Several types of steam winding engines suitable for sinking purposes may be mentioned. Fig. 22 illustrates

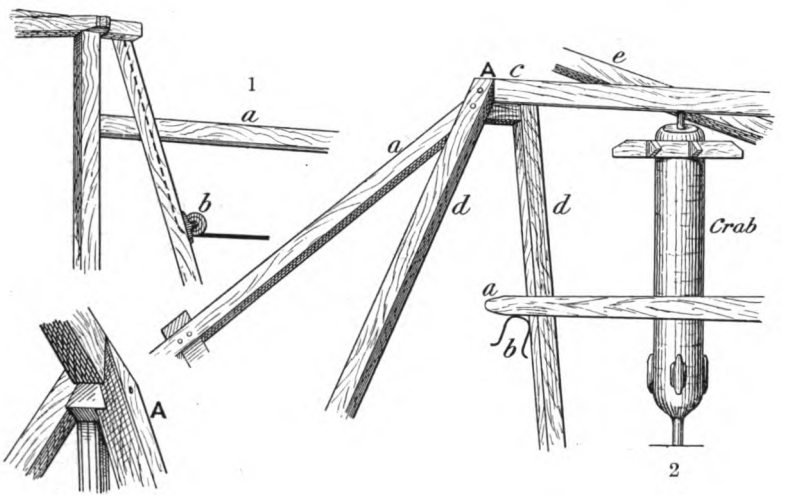

FIG. 18.—Detail of Crab.

1. Crab Supports—(*a*) Support for Crab; (*b*) Friction Roller. 2. Crab—(*a*) Driving Beam, 30 feet long; (*b*) Yoke or Limber for Horse; (*c*) Span Beam, 36 feet long; (*d*) Legs; (*e*) Support (*a* in 1). 3. Details of junction of legs at A in 2.

a single-cylinder portable winding engine with boiler and feed pump, which is a machine particularly well adapted for prospecting or for small mines, where a complete self-contained winding plant is required. It is substantially built and well arranged, a continuous bedplate carrying the engine and boiler. The drum is fitted with a band friction clutch operated by a hand lever and a band brake operated by a

foot lever. The bands are lined with wooden blocks, provision being made for taking up wear. Throttle,

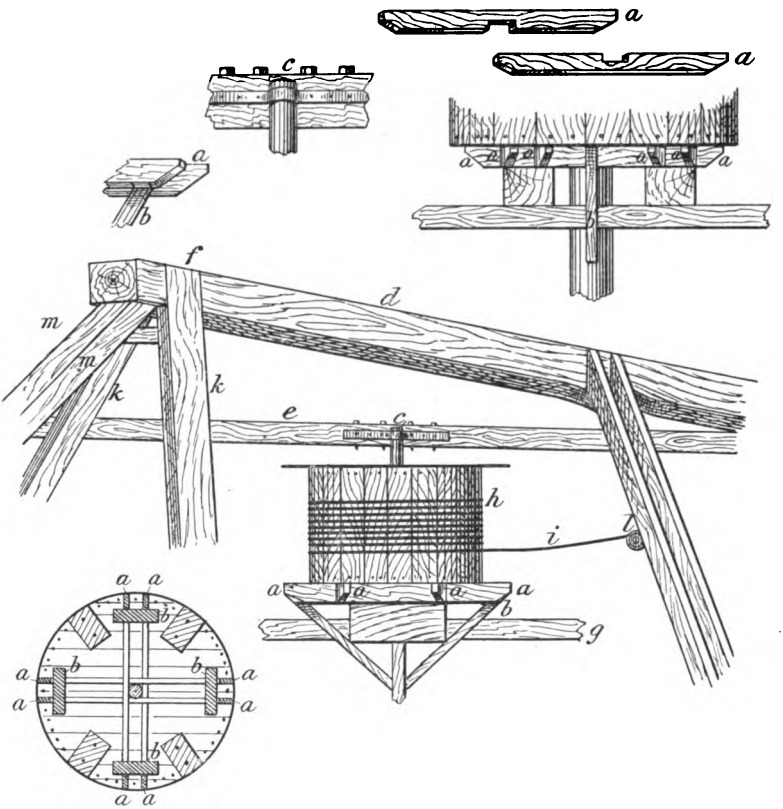

FIG. 19.—Detail of Gin or Whim.

(*a*) Supports; (*b*) Stays fixed to *a*; (*c*) Ring in which axle of gin works in socket; (*d*) Span Beam, 36 feet long; (*e*) Span Beam, 36 feet long (supports to this are not shown); (*k*) Legs notched at (*f*) for supports (*m*, *m*) to fit into; (*g*) Driving Beam; (*h*) Barrel; (*i*) Wire Rope; (*l*) Roller.

clutch, and brake levers are within easy reach of the operator.

A heavy fly-wheel is placed on the outer end of the crank shaft, and may be used to drive other

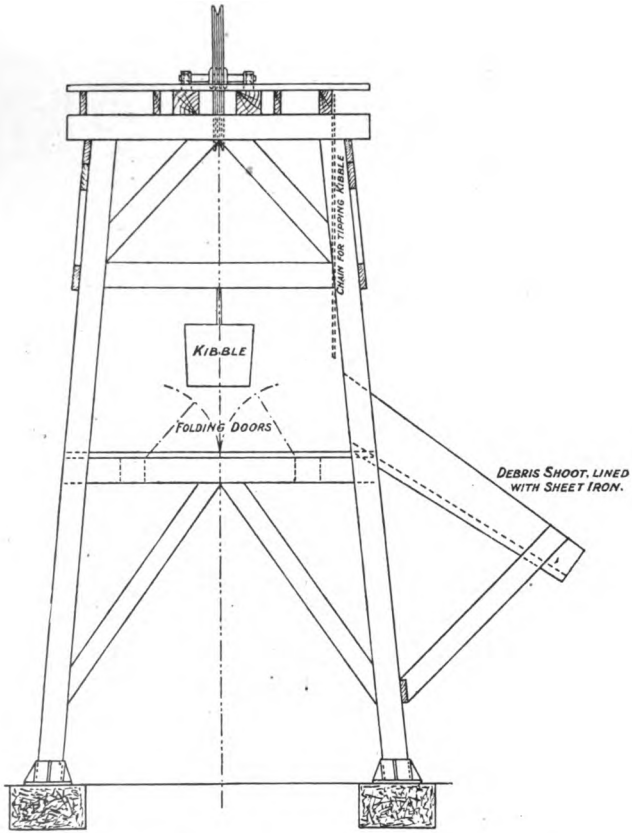

FIG. 20.—Wooden Headgear for use at a Sinking Pit, showing folding doors and rubbish shoot. (Messrs. J. Cook, Sons & Co., Ltd.)

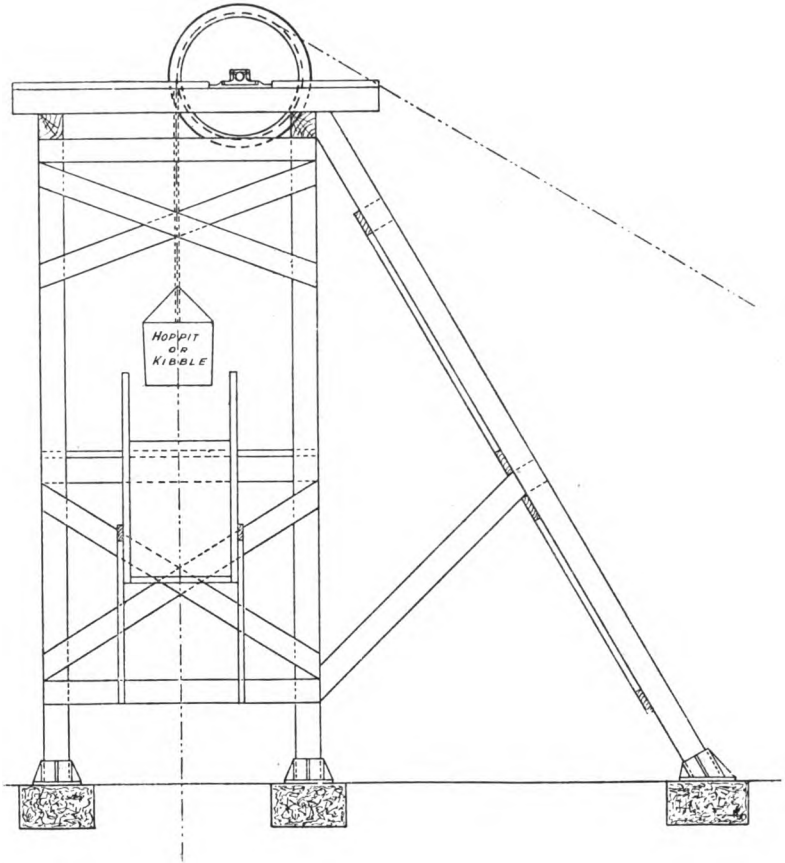

FIG. 21.—Wooden Headgear for use at a Sinking Pit. (Messrs. J. Cook, Sons & Co., Ltd.)

machines. The boiler shell is made of flange steel throughout, and the boiler is fed by a single-acting pump, driven by an eccentric on the engine shaft.

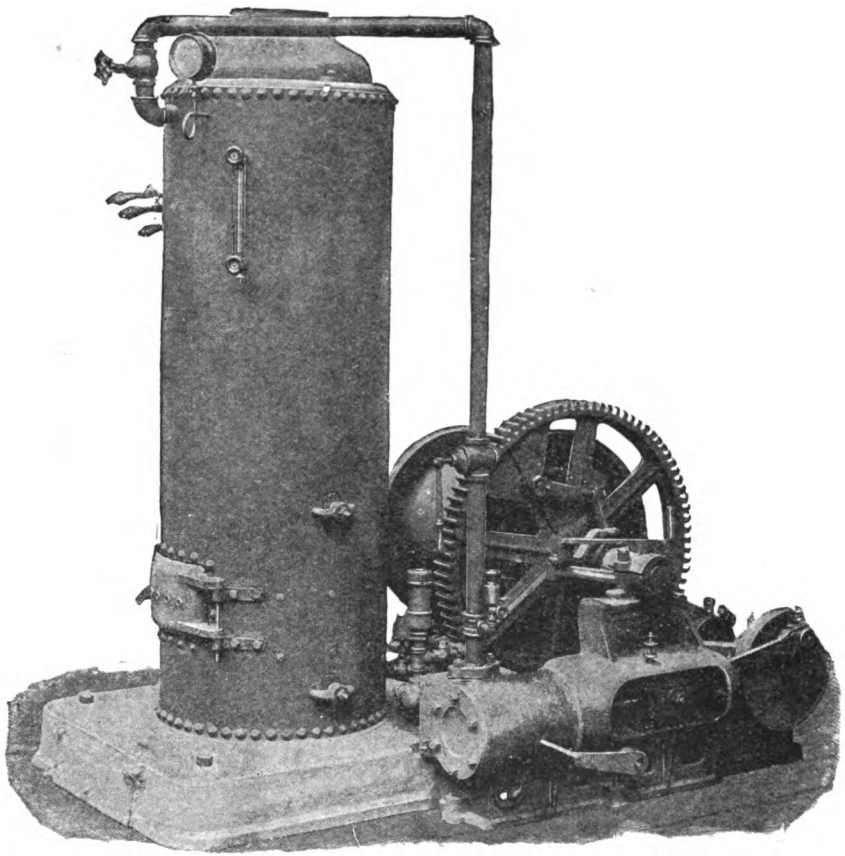

FIG. 22.—Single-cylinder Portable Winding Engine.

The engine operates economically and requires no special foundation.

Messrs. Fraser & Chalmers, the makers of this plant, quote the following standard sizes :—

TABLE III.—*Particulars of Portable Winding Engines.*

Diameter of Cylinder	6 in.	7 in.	8 in.
Stroke	8 „	10 „	10 „
Diameter of Drum	18 „	20 „	20 „
Length of Drum	18 „	20 „	20 „
Diameter of Rope	½ „	⅝ „	⅝ „
Feet of Rope in one Coil	150	165	165
Revolutions one Minute	260	250	240
Horse-power	12	18	22
Gears { No. Teeth in Gear	89	89	89
Gears { „ „ Pinion	20	20	20
Approximate Rope Speed	275	300	286
Maximum Load	1200 lbs.	1800 lbs.	2350 lbs.
Height of Boiler	5 ft.	7 ft.	7 ft.
Diameter of Boiler	30 in.	30 in.	36 in.
Weight complete	4700 lbs.	7000 lbs.	8500 lbs.

Fig. 23 shows a single-drum, double-cylinder geared winding engine, built with band friction clutch, band brake and link motion reversing gear, or with band friction-clutch and band brake, or with band brake and link motion reversing gear, according to requirements, and suitable for sinking a single compartment or shaft of small dimensions to a depth of 1500 feet.

The following Table, supplied by Messrs. Fraser and Chalmers, gives standard sizes of their engines of this type :—

TABLE IV.—*Standard Sizes of Small Stationary Winding Engines.*

Steam Pressure, 80–100 lbs. per square inch.

Cylinders.		Drum.		Diam. of Rope.	Feet of Rope in one Coil.	Average Speed of Rope per Minute.	Maximum Gross Load.	Approximate Total Weight.
Diam.	Stroke.	Diam.	Length.					
in.	in.	in.	in.	in.		ft.	lbs.	lbs.
6	8	24	18	⅝	164	400	2000	4,000
7	10	32	24	¾	247	376	2800	7,000
8	10	32	36	¾	375	360	3650	7,500
9	12	42	40	¾	540	462	4250	11,000
10	12	42	48	¾	650	440	5250	12,000
10	15	48	40	⅞	500	450	6350	18,000
12	15	48	48	⅞	600	471	7200	19,500
12	18	54	48	⅞	670	500	8250	28,000
14	18	60	48	1	670	471	9900	30,200

Fig. 24 illustrates a standard double-drum, double-cylinder geared winding engine, built by Messrs. Fraser

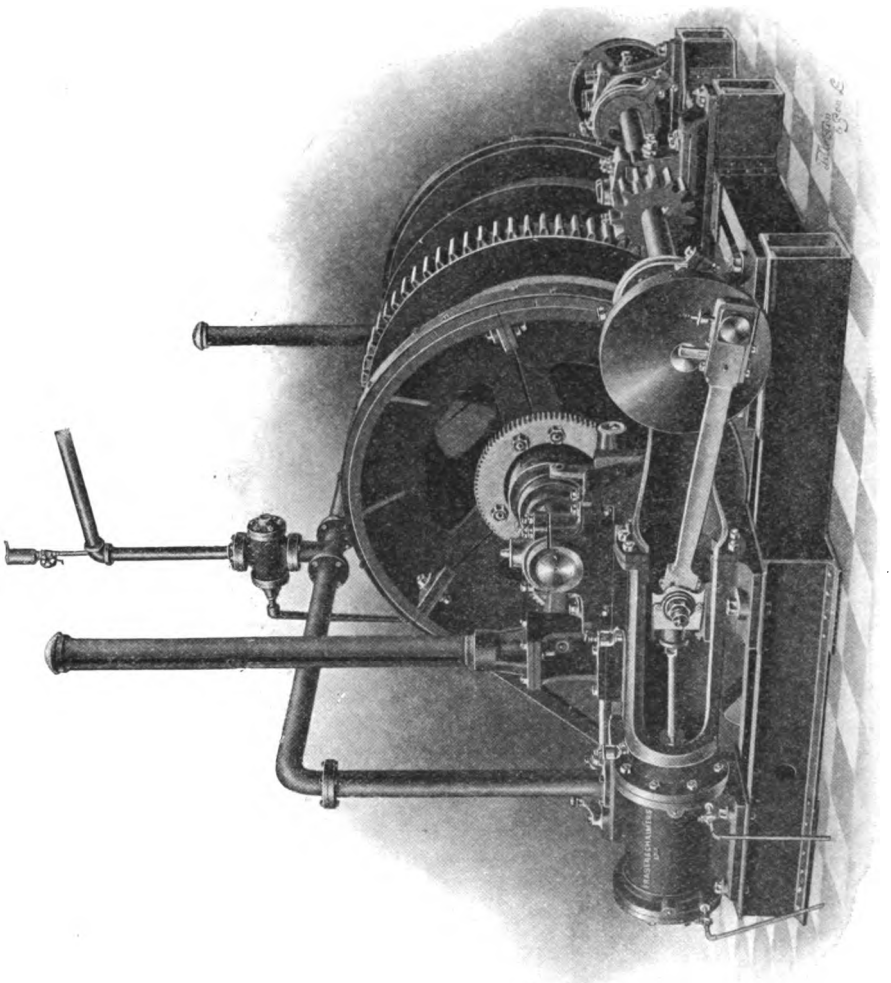

FIG. 23.—Single-drum Winding Engine.

and Chalmers, and suitable for sinking a large size shaft to a depth of 1600 feet. The engine has 14 inches by 18 inches cylinders, the winding capacity being 200

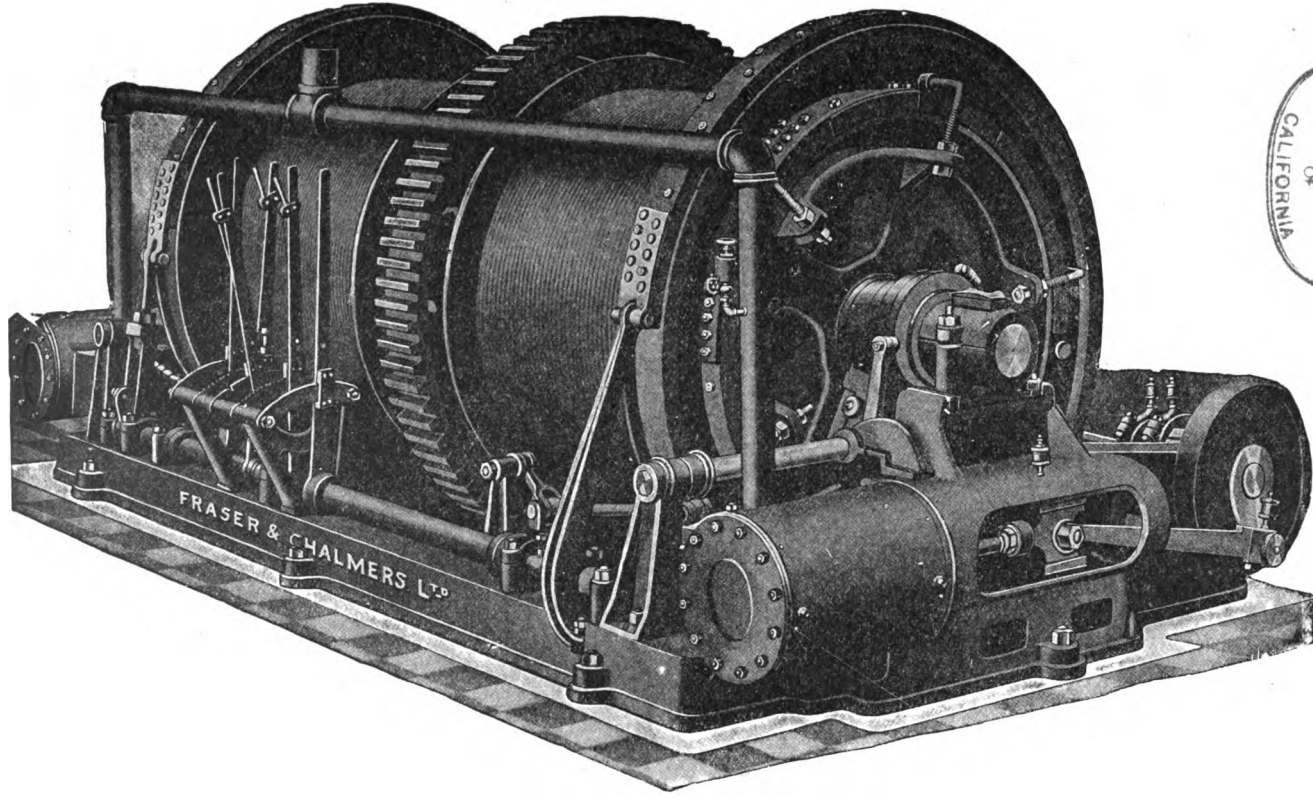

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FIG. 24.—Double-cylinder Winding Engine with two Drums.

tons in 24 hours from a depth of 1600 feet. These engines are built with fixed drums, or drums with friction or jaw clutches, hand brakes, or, if desired, post brakes and link motion reversing gear, and are designed for long-continued work.

Below is given a list of standard sizes of these engines.

TABLE V.—*Standard Sizes of Winding Engines.*

Steam Pressure, 80–100 lbs. per square inch.

Cylinders.		Drum.		Diam. of Rope.	Feet of Rope in one Coil.	Average Speed of Rope per Minute.	Maximum Gross Load.	Approximate Total Weight.
Diam.	Stroke.	Diam.	Length.					
in.	in.	in.	in.	in.		ft.	lbs.	lbs.
8	10	32	24	$\frac{3}{4}$	250	360	3650	12,000
9	12	42	24	$\frac{3}{4}$	330	462	4250	18,200
10	12	42	36	$\frac{3}{4}$	485	440	5250	21,300
10	15	48	40	$\frac{3}{4}$	500	450	6350	29,500
12	15	48	48	$\frac{7}{8}$	600	471	7200	32,500
12	18	54	48	$\frac{7}{8}$	670	500	8250	45,000
14	18	60	48	1	670	471	9900	47,000

Ropes and Kibbles.—Sinking kibbles, bowks, buckets, or kettles, as they are variously termed, are usually fashioned of wrought-iron plates, about $\frac{3}{8}$ in. thick, fastened together at the sides by narrow wrought-iron strips as shown in Fig. 25, on each side of the kibble and riveted, the bottom plate being slightly curved in order to allow of the kibble being easily tipped over. This illustrates a tipping kibble, of the form usually adopted, the kibble (Fig. 26) being swung on trunnions AA, and the bow held in position by the safety catch (B) with a taper pin. On the kibble reaching the surface, it is emptied without detaching it from the winding rope, a rope being fixed to the headgear for the purpose

of swinging it from the mouth of the shaft to a shoot a few yards away. The safety catch-pin is withdrawn and the contents of the kibble shot into the spout which carries the débris to the tipping wagon.

Flexible and Rigid Guides.—Guide ropes are frequently used in sinking pits, especially if the shafts are being put down to a considerable depth, in order to reduce as far as possible the oscillation of the

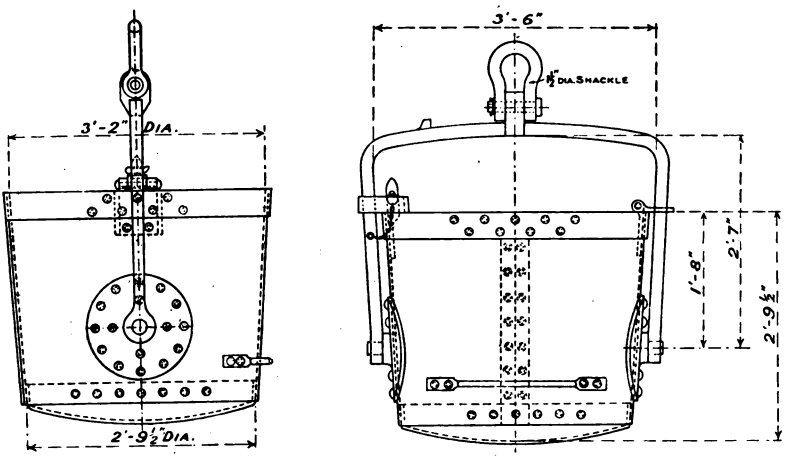

FIG. 25.—Sinking Kibble. (Messrs. J. Cook, Sons & Co., Ltd.)

kibble in the shaft. A "gate" or "rider" through which the guide ropes are threaded, acting as the balancing or steadying medium, is carried above the capel of the rope. In Fig. 26[1] the legs of the cross-bar are fitted with lugs CC, through which the guide ropes pass. These are placed at opposite sides of the rider or gate in order to give a better balance. D is a buffer, consisting of alternate rings of india-

[1] Reproduced by permission of the Council of the British Federated Society of Mining Students.

rubber and iron, which acts as a cushion between the rider and the rope. When a detaching hook is applied, in order to allow of its coming into action by passing through the cylindrical aperture in the headgear, the rider is made hinged in the middle, the hinge being held by a small copper rivet which is easily cut on the application of force. The guide ropes pass over pulleys at the surface and are attached to a windlass, so that they can be lowered as the depth of the shaft increases. The rider terminates some distance above the bottom of the shaft, in order to be safe from injury by blasting and to allow of the freer movement of the kibble. Buffers, similar to that already mentioned, are placed on the guide ropes for the reception of the rider.

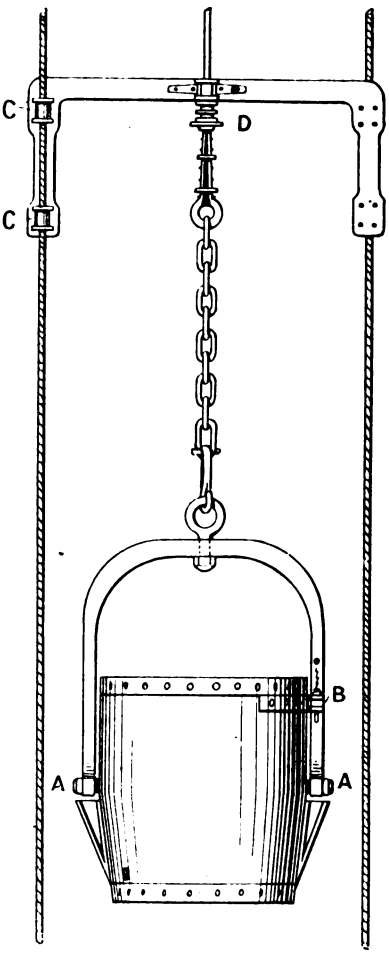

FIG. 26. — Kibble with Rider on Wire Rope Guides.

Both guide ropes and rider should be very carefully and regularly examined, so that liability to sticking of the latter may be reduced to a minimum. The danger that may arise from such an occurrence is both great and obvious.

A form of rider or gate applied to rigid (wooden) guides, which are sometimes used, much resembles a wooden gate, and slides between the guides and above the kibble. Mr. J. M. Maclaren, in his report to the Government of Queensland, 1901, says—writing of this form of rider used at some of the Queensland gold-mines: "The rope passes vertically through the cross-head frame, the lugs of which engage with the guides. As the bucket rises from the bottom and reaches the lowest timbers, a collar fixed on the rope above the swivel hook engages the cross-head frame, which slides along the guides. In its downward journey the frame is caught by stops at the last timbers, and the rope, passing freely through, permits the bucket to reach the 'sink.'

"To prevent undue rotation of the bucket, most shoes are fitted with swivel hooks; without this precaution, and even with a 'Lang's Lay' rope, the bucket is apt to rotate in an alarming manner. An example of the most modern practice in this respect was met with at the Day Dawn Freeholds Consolidated Mine, where the manager has for some time used ball-bearing swivel hooks, to the almost complete elimination of the effects of torsion."

A wooden gate sliding between wooden guides is much more liable to stick than a metal rider through which guide ropes are threaded.

The suspension of the kibble from the rope is a matter of some importance, and is usually done through the medium of a spring or safety hook (see Fig. 27). Locked-coil ropes are now largely used for suspending sinking kibbles in preference to "ordinary" or even "Lang's Lay" ropes, as causing less twisting to the kibble than any other form.

Covering Doors and Guide Ropes

Pit-Mouth Frame.—To allow of the lorries on which the banksmen stand passing over the pit top in the manner described on page 89, four balks are often placed across the mouth (Fig. 28) carrying bridge rails on which the lorry and the bogie into which the kibble empties may be run. Thus a square framework is formed over the pit mouth, and, on the landing of the hoppit or kibble, is completely covered. The lorry is sometimes called the running bridge or "giddy." It should be protected at the sides with proper fencing.

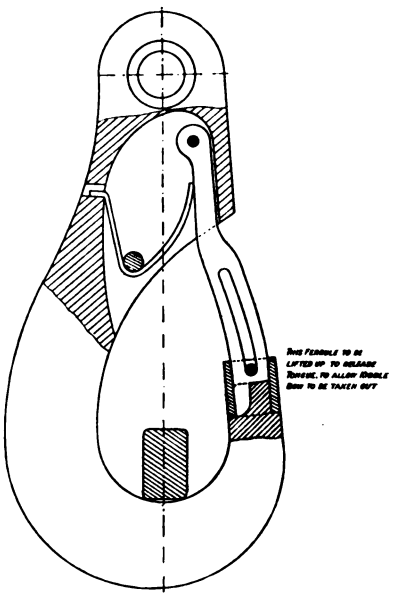

FIG. 27.—Spring Hook used for connecting the Kibble to the Rope. (Messrs. J. Cook, Sons & Co., Ltd.)

The following arrangement, patented by Professor Galloway in 1875, is an ingenious method of applying flexible guides to a sinking pit and working the covering doors. In Fig. 29 the guide ropes are shown passing over the two pulleys (*a*), resting on beams about 20 feet above the landing stage, and thence descending to the surface level, where they are wound on two drums (*b*), which are part of a screw steam crab; the drums being capable of being worked separately or together, as may be necessary, to provide for any irregularity in the length of the guides.

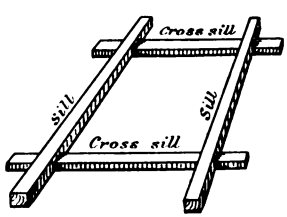

FIG. 28.—Arrangement of Sills at the top of a shaft.

The lower ends of the guides are attached to the walling cradle by means of bridle chains, and the cradle, being always in the shaft whilst sinking operations are being carried on, gives the necessary amount of tension to the guide ropes. The doors (*d*, *d*) (Fig. 30), when closed, touch the guide and winding ropes—which are, of course, in the same plane—on opposite sides, and are worked by means of the handles (*b*, *b*); these, on being pulled down or raised up, open or shut the doors simultaneously.

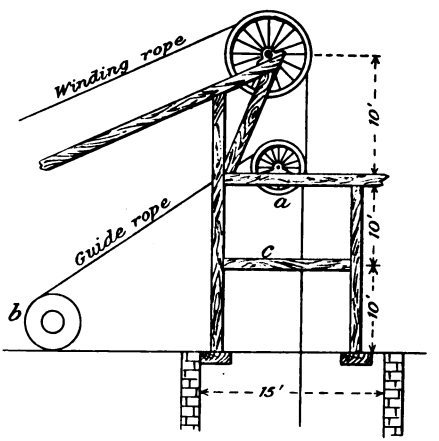

FIG. 29.—Surface Arrangement of Guide Ropes.

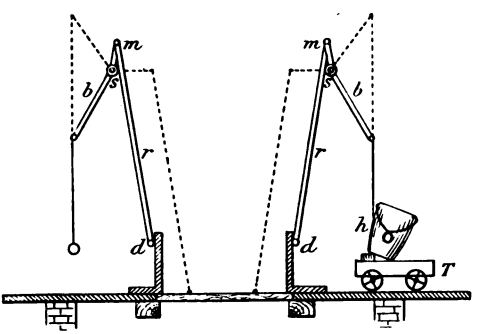

FIG. 30.—Doors covering Mouth of Shaft, and Levers for working same.

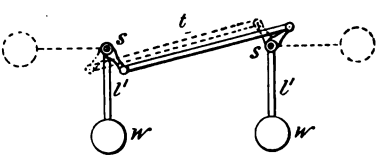

FIG. 31.—Balance Weights and Levers for opening and closing doors at mouth of shaft.

(*d*, *d*) Doors; (*l'*, *l'*) Levers always parallel to the doors; (*b*, *b*) Handles; (*m*, *m*) Cranks; (*r*, *r*) Connecting rods; (*s*, *s*) Crank shafts; (*t*) Connecting rod; (*w*, *w*) Balance weights; (*T*) Tram.

The system of levers and balance weights by which this is effected is shown in Fig. 31. The doors are

situated at the landing level (*c*, Fig. 29), and when shut, entirely cover the 6 feet square opening stage or platform, four pieces of rail laid over their upper sides forming the connection (when the doors are shut) with the tramway leading to the waste tips. The doors,

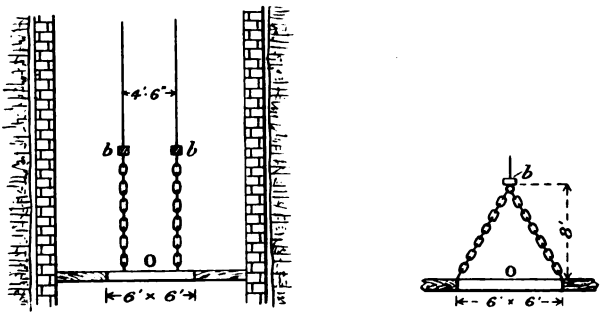

FIG. 32.—Walling Platform.

when open, constitute a fence to the uncovered pit. The walling platform or cradle is shown in Fig. 32. When walling operations are being carried on, the opening O is covered with planks. The walling is carried up to a height of 3 feet before raising the platform by means of the steam crabs. After this has been done the platform is steadied by fixing six radial bolts in small holes left in the walling.

CHAPTER III

DRILLING AND BLASTING

BEFORE entering upon an account of the principal methods adopted in the sinking of shafts, it is advisable to give some description of the more common means used for excavating the ground.

Tools.—The tools, other than those used for drilling and blasting, which are described below, consist chiefly of stone hacks (Fig. 33)—the head of which weighs about 4 lbs.,

FIG. 33.—Stone Hack.

and is mounted on a shaft of hickory, acacia, or ash wood—pointed shovels (Fig. 34), and steel wedges (Fig. 35).

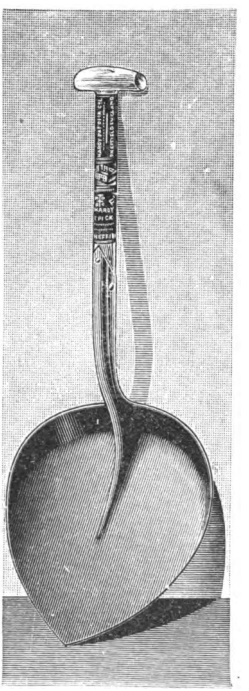

FIG. 34.—Sinker's Shovel.

Drills.—Hand drills are undoubtedly more largely used in the sinking of shafts, especially colliery shafts, than power drills; though the latter are now of more frequent application than they were some years ago, the advantages resulting from their use being more fully realised than was formerly the case. The question of the choice resolves itself largely into one of convenience and cost. A power drill occupies a good deal

of room—an important matter when the comparatively restricted area of a shaft bottom is considered—and is not, when blasting operations are about to commence, so easily and quickly removed as are hand drills; though this criticism can hardly be said to be valid in respect of pneumatic hammer drills, which have recently come into use in mines.

FIG. 35.—Steel Wedge.

Where labour is scarce and wages high, or where the rock to be sunk through is excessively hard, the balance of advantages will be in favour of power drills.

FIG. 36.—Hand Drill.

Hand Drilling.—Hand drills (Fig. 36) are most frequently made of octagonal cast-steel bars, though sometimes of iron bars with hardened cutting points and heads. They are "flat-nosed," and of different sizes and lengths, viz., say in sizes of 2 inches, $2\frac{1}{2}$ inches, and 3 inches, and lengths varying from 2 feet to 4 feet 6 inches. In sinking an 18 feet diameter pit, the stock of drills required will be between 40 and 50.

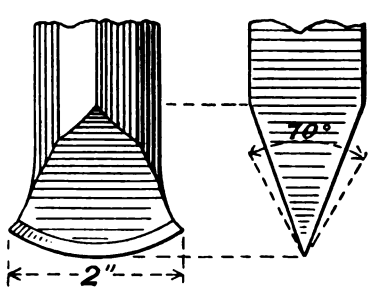

FIG. 37.—Point of ordinary Hand Drill.

The angle between the faces of the drill point varies with the hardness of the rock to which it has to be applied, but does not exceed 70 degrees (Fig. 37). It is of importance that only the best steel should be used in their construction, and that the sharpening should be carefully attended to.

Iron or steel-headed sledgers (Fig. 38) of from 4½ to 9 lbs., having shafts of about 2 feet 6 inches long, are used for striking the chisels. The shaft should be made of ash, acacia, or oak — the more elastic the wood the better.

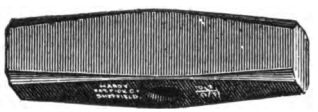

FIG. 38.—Steel Head of Sledger.

The hole may be commenced by one man using a short drill or chisel and short-shafted hammer, and after each blow of the hammer turning the chisel in the hole and working it up and down in order to prevent sticking and ensure a cylindrical hole being made. When a depth of from 9 to 12 inches has been drilled, the longer drill may be applied, and the drilling be performed by two men, one holding and working the drill, the other striking. When deep holes are being drilled and the rock is not too hard, two men frequently "jump" a hole—that is, lift and throw down the long heavy drill.

Mechanical or Power Drills.[1]—Screw hand-worked drills are seldom if ever used in sinking, so need not be described here.

Power drills may be driven by steam, compressed air, electricity, hydraulic power, or by oil. But in sinkings, power is practically only applied by compressed air or (rarely) electricity.

The machines may be percussive or rotary, but the former type is the more general. They are designed to simulate and carry out the three operations of hand drills, viz. the blow, the rotation, and the advance.

[1] Trade catalogues frequently afford most useful information, and the directions for operating drills contained in pages 29–33 of the Ingersoll-Sergeant Drill Co. Catalogue 41 (1898) is a case in point, containing valuable hints of a practical nature in respect to drills and drilling, upon which the author has been kindly permitted to draw.

Percussive drills consist of the following parts: a cylinder in which a piston is made to move backwards and forwards; a piston rod, to the end of which is attached the chisel or cutting tool; the arrangement which effects the rotation of the drill or piston rod consisting of a rifled bar and ratchet wheel (Fig. 39); the feeding forward device comprising a cradle worked forward by hand by means of a screw

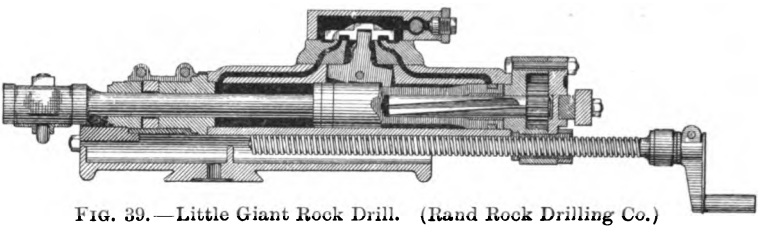

FIG. 39.—Little Giant Rock Drill. (Rand Rock Drilling Co.)

which revolves in a big nut attached to the machine. All these parts are clearly explained in Fig. 41, which represents a longitudinal section of an Ingersoll-Sergeant drill, the spiral bar, rotating ratchet, and pawls being separately illustrated in Fig. 40. The pawls are forced out into the ratchet teeth by small spiral springs.

For making and sharpening the X or + bit (Fig. 42), the blacksmith requires a set of "Swages" die and dolly of the type shown in Fig. 43.

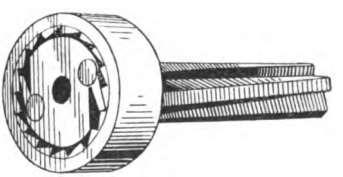

FIG. 40.—Spiral Bar and Rotating Ratchet.

Respecting the shape of the bit, the above particulars are to some extent borne out by Mr. F. Coulson,[1] who is of the opinion that it is desirable to use as simple a bit as possible, so as to save blacksmith's work. He remarks: "For hard stone, + or X

[1] "Sinking with Rock Drills," by Frank Coulson, *Trans. Inst. M.E.*, vol. viii. p. 21.

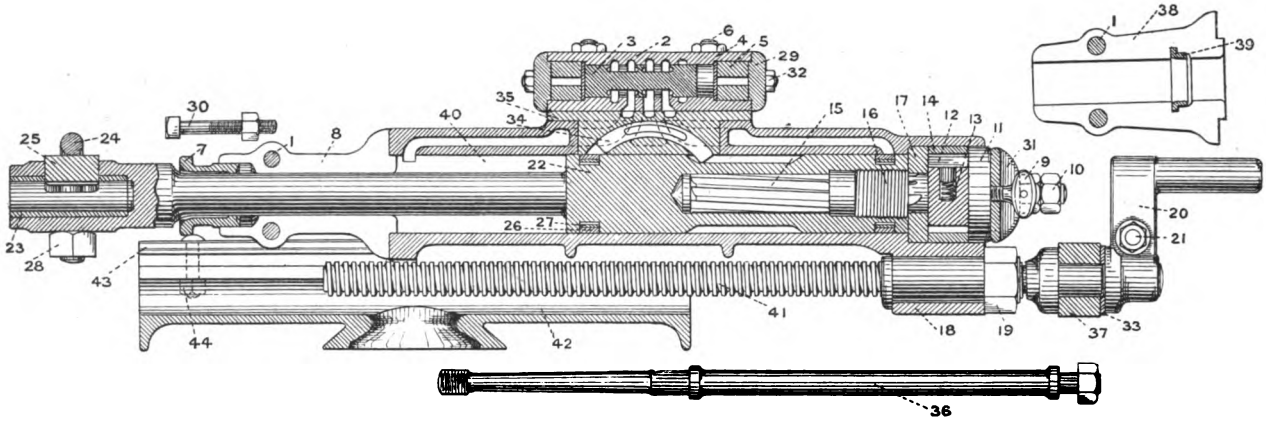

FIG. 41.—Ingersoll-Sergeant "Auxiliary Valve" Drill—Square Guide Cylinder.

Indication Numbers of Parts.

1. Front Head Bolts and Nuts.
2. Steam Chest Bare.
3. Valve.
4. Valve Washers.
5. Valve Buffers.
6. Steam Chest Studs and Nut.
7. Split Gland.
8. Split Front Head for Steam.
9. Thumb Screw.
10. Through Bolts and Nuts.
11. Back Head.
12. Rotating Pawls.
13. Pawl Springs.
14. Rotating Ratchet.
15. Rifle Bar.
16. Brass Nut.
17. Rotation Washer.
18. Feed Nut.
19. Feed-nut Nut.

Indication Numbers of Parts.

20. Crank.
21. Crank Bolt and Nut.
22. Piston Bare.
23. Piston Bushings.
24. U Bolts and Nuts.
25. Round Keys.
26. Piston Rings.
27. Piston Ring Springs.
28. U Bolt Nuts.
29. Steam Chest Covers.
30. Gland Bolts and Nuts.
31. Cushion Springs.
32. Chest Cover Studs.
33. Washer for Crank.
34. Auxiliary Valve.
35. Auxiliary Valve Seat.
36. Standards and Nuts.
37. Cross Heads.
38. Special Front Head (for air only).

Indication Numbers of Parts.

39. Cup Leather.
40. Square Guide Cylinder Bare.
41. Feed Screw, Square Thread.
42. Shell without Caps.
43. Square Guide Shell Caps.
44. Shell Cap Bolts.

Parts for Drill with V Guide Cylinder.

45. V Guide Cylinder Bare.
46. V Guide Shell Cap.
47. V Guide Shell Without Caps.
48. V Guide Shell Cap Bolts.
49. Goose Neck.
50. Goose Neck Bolts and Nuts.
51. Feed Screw.
52. Feed Nut.
53. Feed Nut Clamp.
54. Feed Nut Clamp Bolts.
55. Brass Spiral Nut.

bits are most suitable. For sandstone, bits with a broad edge, not sharpened, and for soft ground" bits shaped as in Fig. 44 are most suitable. "The + bit is more easily sharpened than the X bit, but will not bore in places where work can be done by the latter; whereas the X bit will bore under all circumstances where work

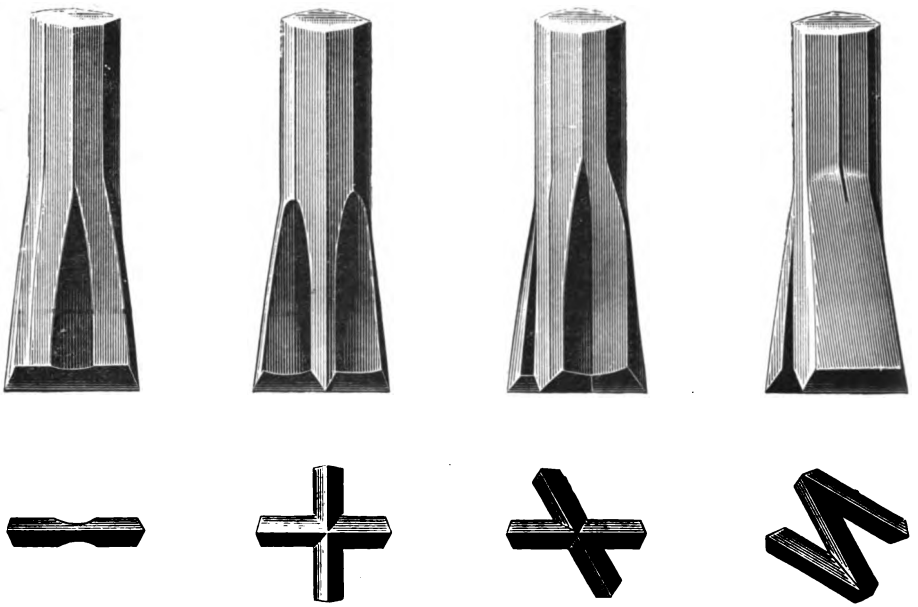

FIG. 42.—Types of Bits of Power-driven Drills. (Ingersoll-Sergeant Drill Co.)

can be done by the + bit. The bit shown in Fig. 44 bores more rapidly; having a bit cut out of the sides, it keeps the hole round, and prevents canches being formed. It is the best all-round drill except for very hard stone."

The object aimed at in the design of all bits is the keeping of the hole drilled as round as possible. The plain chisel shape is in commonest use, but, as mentioned above, the X, Z, and horseshoe shapes all have their particular vogue.

Steel Bits. — It may be stated, as a general rule, that the single-edge bit should be used whenever it is possible to apply it, as it is so simple: in hand-drilling it is always preferred. It cannot be used with percussive drills in hard rock, because the blow is so strong that the edge will not stand. Here is where double-edging comes in to advantage, for having plenty of power behind it, that power may be distributed over two or three edges, and thus gain an advantage.

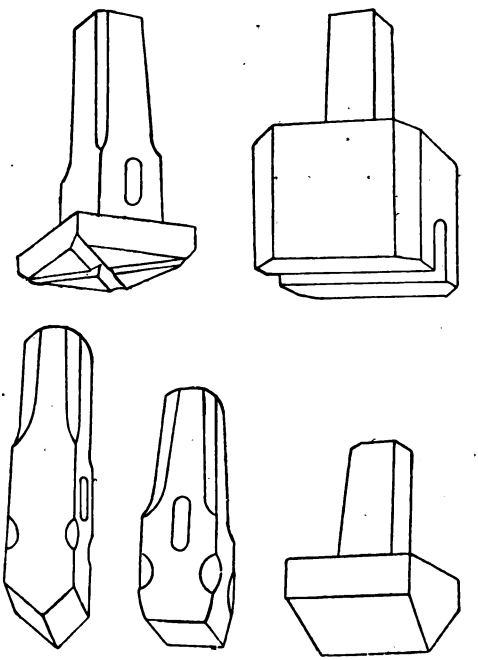

FIG. 43.—Swages, Die, and Dolly. (Ingersoll-Sergeant Drill Co.)

A straight edge on a marble bit will result either in broken edges or in rapidly dulled edges, and in sticking. It is a curious fact that the point on the edge of the marble bit should not be in the centre, but a little to one side, in order to prevent sticking and to do the best work. The reason for this is seen when it is understood that the drill in turning around after each blow would, were the point in the centre, shape the bottom of the hole like a cone, while with the point to one side, the shape is that of a

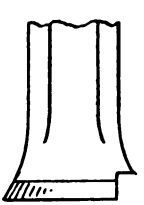

FIG. 44.—Special form of Bit for drilling in soft rocks.

truncated cone, which offers less chance to stick. The edge might be curved instead of tapering to a point; but the taper is preferred, because more readily sharpened. The advantage of a taper or a curve is that it distributes the work more evenly.

A straight edge, when used for hole-drilling, brings most of the work upon the outside points of the bit. These points turn around through the largest circle—that which limits the diameter of the hole; and, besides, they have to break up the stone at the wall where it offers the greatest resistance. The taper or curve eases this condition of things by changing the bottom of the hole so that it has no sharp corner.

Sandstone has a singular effect upon drill bits. Though sandstones are usually soft, the bits cannot be finely pointed, but, on the contrary, should be flattened. A bit with a knife edge when used in sandstone will have its edge sharpened like a razor; the faces of the bit gradually become concave. This is natural, because, as the bit embeds itself in the grit of the rock, it is rubbed as though on a grindstone. The stone is not usually hard enough to dull the sharp line of the edge, so that the more this bit is used the sharper it gets. It cannot, however, be used for a very long time, as the points, or outside ends, of the bit become flattened and dulled, and, what is a still greater objection, the ends become tapered. All this arises from the hard work and the great rubbing experienced at the walls of the hole.

The most successful sandstone bit is undoubtedly that with the flat edge. This bit is nothing more than a flattened-out piece of steel, with no more edge to it than there is to the side of one's finger. It is sometimes called the "stub" bit. Exact dimensions of this bit

that will apply in all cases cannot be given, but the most popular are 1½ inch length of face, and from ⅜ to ⅝ inch in width. The cutting face should be square, and the bit should be kept thin to ensure fast cutting; but if a cornered hole results, it should be thickened a little. It is usual to simply dress it up by heating it and hammering it to square edges, the chief work having to be done upon the outside ends in order to keep them square and up to gauge.

There is so much metal in the sandstone bit that it is not rapidly worn away by the grit. It is, therefore, a common thing to see one of these bits in use for half a day, drilling a great many holes in different places, without having to be sent to the shop. When starting a hole it pounds upon the rock like a base-drum, and an inexperienced looker-on would naturally suggest a sharper edge.

There is no question about the advantage of the flat bit in sandstone quarries so far as the blacksmith work is concerned. It will actually put in a hole faster, because, when drilling sandstone, the process is not a chipping but a crushing one. Marble, or any other hard, crystalline substance, needs a sharp edge to throw a chip, whereas sandstone will crush.

Prior to the use of the percussive drill there were few, if any, drill bits which had much value above that with the single edge. Even in artesian well-boring, where the blow is heavy, the single-edge bit has held its place against many patented bits.

Fig. 42 shows a modified form of single-edge bit in comparison with several other bits which are used with success with percussive drills. The flattened or grooved shape—given the single-edge bit—at its centre, is for the purpose of discharging the cuttings. As the

centre of any bit performs but little work, it may readily be cut away without reducing efficiency. It may safely be said that, apart from the various forms of single-edged bits previously described, the +, X, and Z bits are the only really important bits in use with percussive drills.

The + bit is the most popular percussive drill bit in use. It seems to be a happy medium in that it accommodates both the drill runner and the blacksmith, though, were the blacksmith's wishes not consulted, it is possible that the X bit would replace it almost everywhere.

Out of several hundred inquiries sent out by the Ingersoll-Sergeant Company to mining and quarrying men as to which bit was preferred, the + or the X, opinions differed largely, but the weight of evidence was in favour of the + bit.

As a general rule the + bit had better be used wherever the rock will admit, for the simple reason that it is more readily dressed by the blacksmith.

The two bits are very much alike, in that they have the same extent of cutting edge, but they differ in that the edges in one case cross at right angles, and in the other at acute angles. As the bit, when at work, turns around after each blow, it is obvious that in the case of the + it may strike four times in the same place while turning the circle, while with the X it can only strike twice in the same place. A + bit, when turned one quarter of the circle, or 90°, may imbed itself in exactly the same groove that had been made by a recent blow, and if this striking in the same place is frequent, and the rock is soft enough to admit of rapid drilling, the hole will become "rifled," that is, it will not be round. Any one who has had much to do with drill-holes knows that

a "rifled" hole is a great nuisance. As the X bit has only half as much chance to strike in the same place as the +, it offers only one-half of the opportunity to "rifle" the hole. It is a common thing for percussive-drill manufacturers to receive complaints that "the drill will not put in a round hole"; the invariable remedy is to change the bit, and, as a general thing, the X bit is the thing to use.

In the blacksmith's shop the + bit is invariably preferred. In using the dolly the blacksmith finds that by turning it one-quarter it fits the bit, and, owing to the rectangular and uniform construction of the bit, he has no difficulty in keeping it at gauge, while with the X he must turn his dolly one-half the circle, and, in doing so, the bit must either be turned around, or he must send his helper on the other side of the steel. It is because of this very condition of things, as illustrated in the blacksmith's shop, that the X bit, when turning around in the hole, is less liable to strike in the same place, and drills a better hole. Persons using the + bit, and having difficulty with "rifled" holes, can try the experiment by simply knocking the flanges of the bit together in the blacksmith's shop, while the steel is hot and after it has been dressed. If they find that this bit will drill a more satisfactory hole, they had better throw away their + dolly and send for an X, notwithstanding the opinion of the blacksmith.

In trap rock, granite, and other uniform rocks, the + bit does good work, and drills a round hole because the rock is uniformly hard, and the drilling is consequently slow.

The Z bit is designed for and used to a moderate extent in soft rocks, or in work where seams and

soft places are found in the line of the hole. This bit is sometimes modified by having the middle edge straight across, thus making an I instead of a Z; but there is little preference between the two—both are difficult enough for the blacksmith to dress.

Fig. 45 shows the Stephen's parallel double-edged

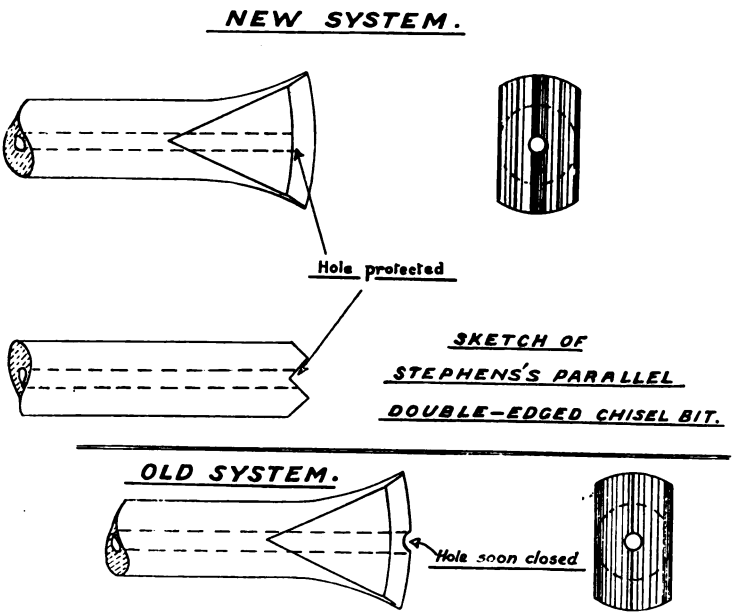

FIG. 45.

chisel bit—which is a comparatively recent invention. It was found that the hole in the drill used for carrying the air-water spray in the single-edged chisel had a tendency to elongate after forging and further reduce the area of cutting edge, so that instead of making the hole come through a cutting edge shaped like an inverted V, the apex of the Λ is cut V-wise, so that two cutting edges are formed, and there is

the additional advantage that the hole is always protected.

The Hardy Patent Pick Co. of Sheffield remark in their catalogue that, "The fault with many who are unaccustomed to the treatment of solid steel drills is that, in hardening and tempering, they heat the point too far up, and, after tempering the point, they plunge it into cold water while a portion of the drill is yet at a red heat, the consequence being that the portion which is at red heat at the time it is plunged into water is made as brittle as glass, and will break off with the first blow or two when put into work."

The following directions as to hardening and tempering of steel drills should be observed :—

In no case should the steel be heated to a greater heat than cherry red, nor farther up than is absolutely necessary for forging; and when it is sharpened the point should be lightly and quickly hammered until it is quite black; and after being pointed it is advisable to lay the drill down to cool before it is tempered; though it is not absolutely necessary, so long as it is not red hot too far up from the point.

In hardening, the drill should not be heated farther up than an inch from the cutting point, then dipped into cold water for about three-quarters of an inch, leaving one-quarter of an inch at a red heat, as shown at the point of Fig. 46; this will be sufficient to allow the temper to run down to the extreme point; when this takes place, plunge the whole into water. Care must be taken, however, to see that no part of the drill is at a red heat when it is so plunged, or it will be made brittle and break off when put to work.

There are a great many power drills on the market, all doing good work, but it is impossible to describe

all of them in these pages. Having illustrated two well-known American types, attention may be drawn to two English drills, viz. the "Climax Imperial" hammer drill, which is shown in Figs. 47 and 48; and the

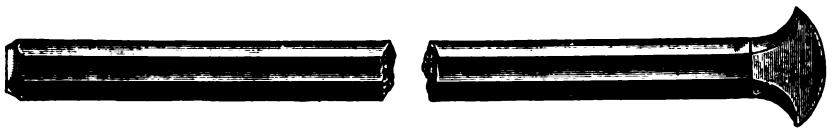

FIG. 46.—Showing Mode of Hardening and Tempering Drill Bits.

"Little Hardy" rock drill, illustrated in Fig. 49, which shows the general arrangement. The salient feature of the construction of the latter drill is the circular dis-

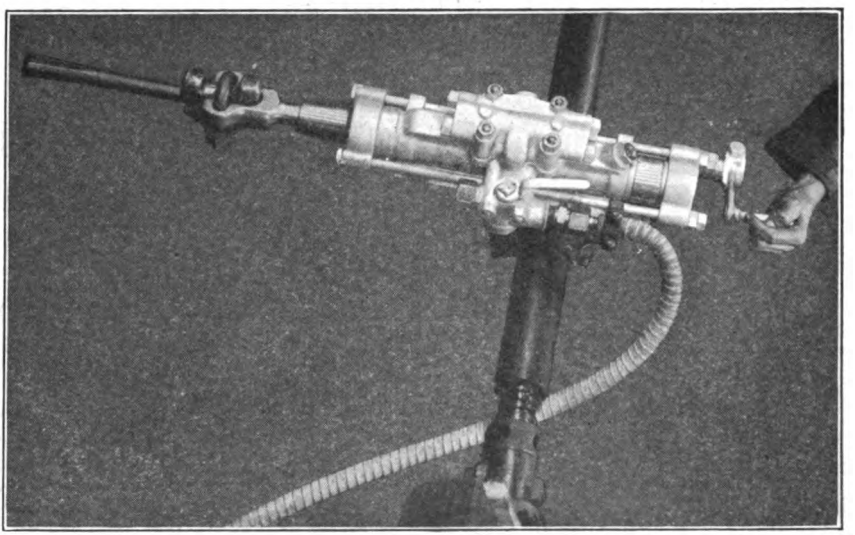

FIG. 47.—General View of "Climax Imperial" Hammer Drill.

tributing valve, which is thrown over by live air or steam fed to the end valve pistons by special ports in constant communication with the main inlet. There are no tappets, guide bolts, or other mechanical con-

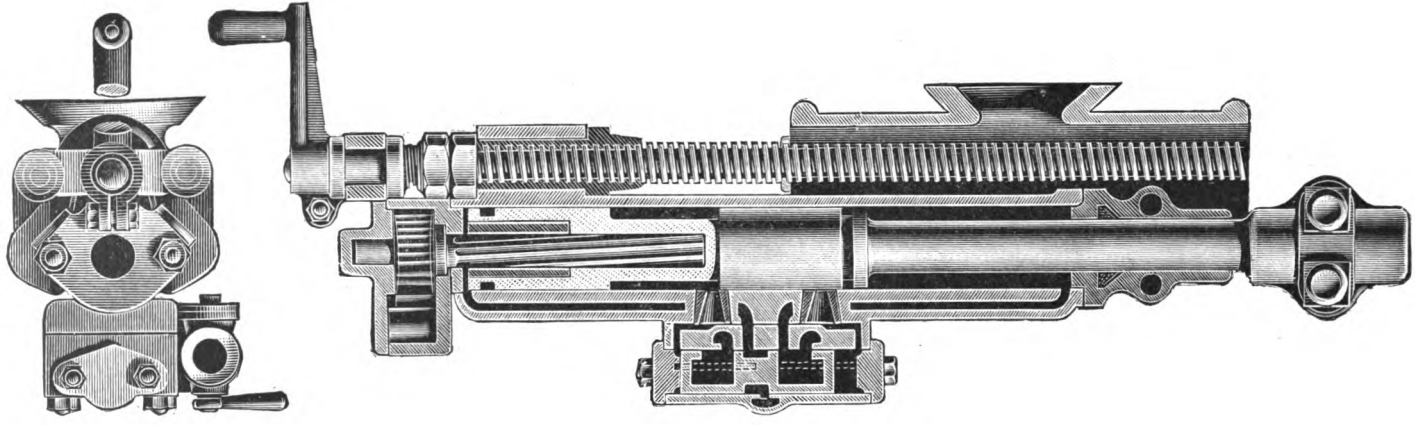

FIG. 48.—Section of "Climax Imperial" Hammer Drill.

nections between the valve and the drill piston. Consequently there is nothing to lessen the force of the blow or to cause battering and breakage to any part of the valve motion; the defects common to all "tappet" machines and those fitted with so-called "auxiliary" valves being entirely eliminated. In this system the valve is automatically locked in its position by the full air or steam pressure acting upon the whole surface of one of the end valve pistons, the opposite one being open to complete exhaust. Variable valve

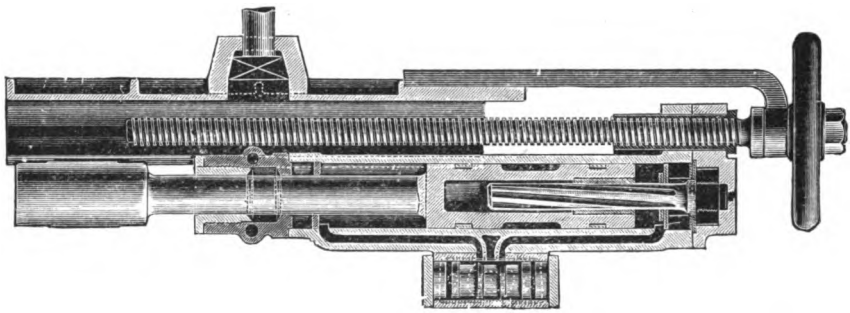

FIG. 49.—"Little Hardy" Rock Drill.

speed, due to wear or fluttering of the valve, is rendered impossible. The valve is said to be unique in speed of travel, being thrown at full pressure. Thus with a 3-inch drill, 6-inch stroke, working at a pressure of 60 lbs. per square inch, 600 to 650 blows per minute are struck, each blow of maximum power for the cylinder area. The drills work well at the low pressure of 40 lbs. per square inch, striking 400 to 500 blows per minute, and doing very good work indeed in the hardest rocks at this low pressure. It is claimed for the machines that they work equally well under steam or compressed air, and that they need no special fitting to change from

one form of motive force to the other. There are no rubber parts whatever in the drills, a most important feature. Wear to the circular piston valve is slight, and lengthy use does not render its action less positive.

Walker's Sinking Frame for Rock Drills.[1]—A method of mounting rock drills for sinking purposes is shown in Figs. 50 and 51, the system being known as Walker's Patent Sinking Frame, and the drills used in this instance being the "Daw." The points in particular, claimed on behalf of this arrangement by the owners of it are—

1. Increase in speed, and reduction in cost of boring.
2. The enhancement of the personal comfort and safety of the men in the shaft.
3. Minimising of accompanying risks in sinking.

The frame was adopted at Sherwood Colliery, near Mansfield, Derbyshire, in sinking two shafts 25 feet 6 inches in diameter. The circular frame (*a*) is 8 feet in diameter and has an annular tee slot cast in its entire circumference, fitted into which are clamps carrying telescopic arms (*b*) which project to such an extent as to approximately correspond with the diameter of the shaft, whatever that may be. Upon these arms are mounted the Daw drills. The whole arrangement, with drills, is put together at the surface, and lowered into the shaft bottom by means of winch and guide rope (*c*); and as soon as the holes are drilled is raised to the surface again. It is claimed that a round of 60 holes can be drilled 6 feet deep in hard limestone and the gear raised to the surface in $2\frac{1}{2}$ hours.

Dust produced in Drilling. The dust produced in drilling in hard rocks of a quartzitic nature has

[1] See also p. 120.

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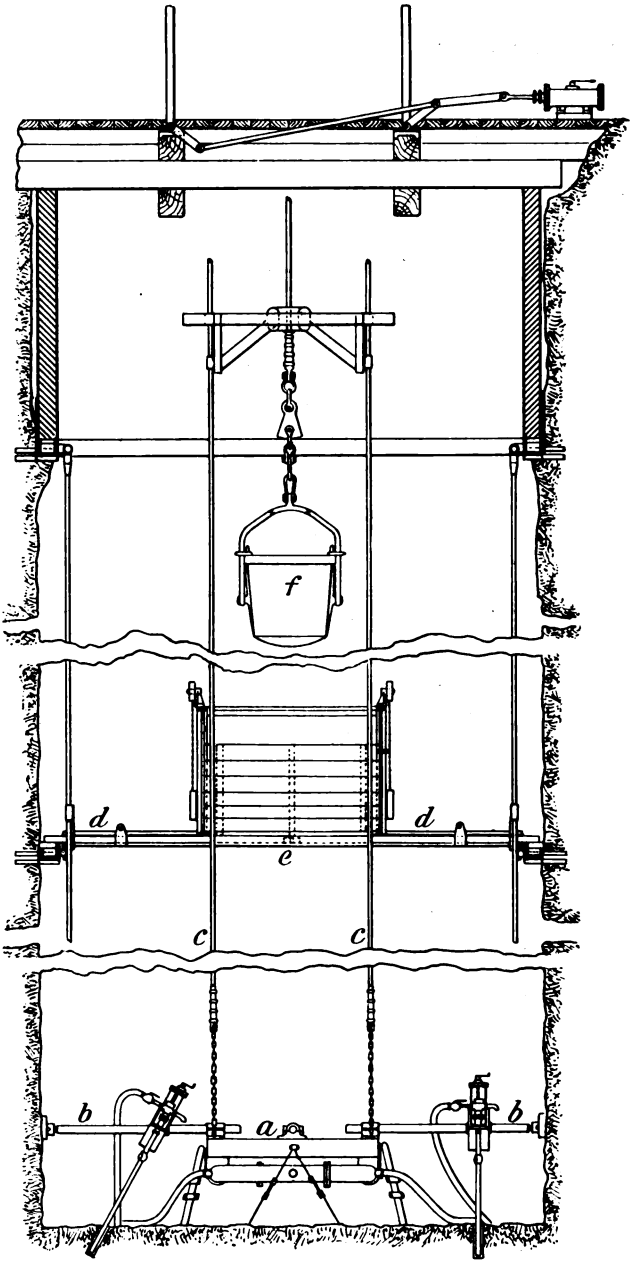


FIG. 50.—Walker's Sinking Frame.

been shown to be one of the chief causes of miners' phthisis, and many devices have recently been adopted with the view of allaying it. Messrs. R. Stephens and Son, of Carn Brea, Cornwall, have devised an arrangement in which a nozzle on the drill is so arranged that a quantity of water is discharged in either a thin fine vapour or a heavy shower as desired. The dust allayer is attached to the air tube of the rock drill by means of a nipple and cup forming a ball-and-socket joint, so that the discharge can be directed

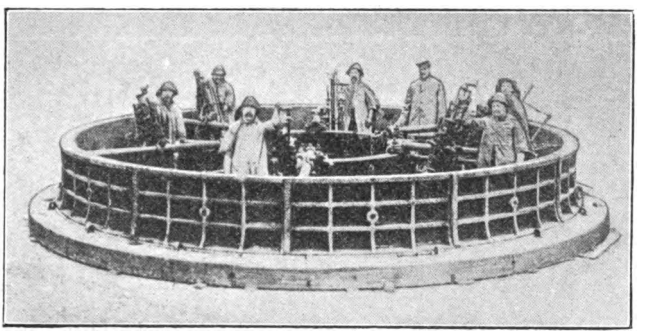


FIG. 51.—General View of Walker's Sinking Frame.

to any required point within a radius of 3 feet, and is operated by the man who is running the drill, the operations being controlled by the air-tap handle only (see Fig. 52).

In the "Climax Imperial" drill, water is employed through hollow drill steel to effect the same purpose. By the movement of a handle the water is admitted to the cutting edges of the drill bit through the borer, and by the further forward movement of the same handle, the air is also admitted to the drill as well as to the feed cylinder, by which arrangement the operator cannot fail to use water in the hole, as the machine cannot be

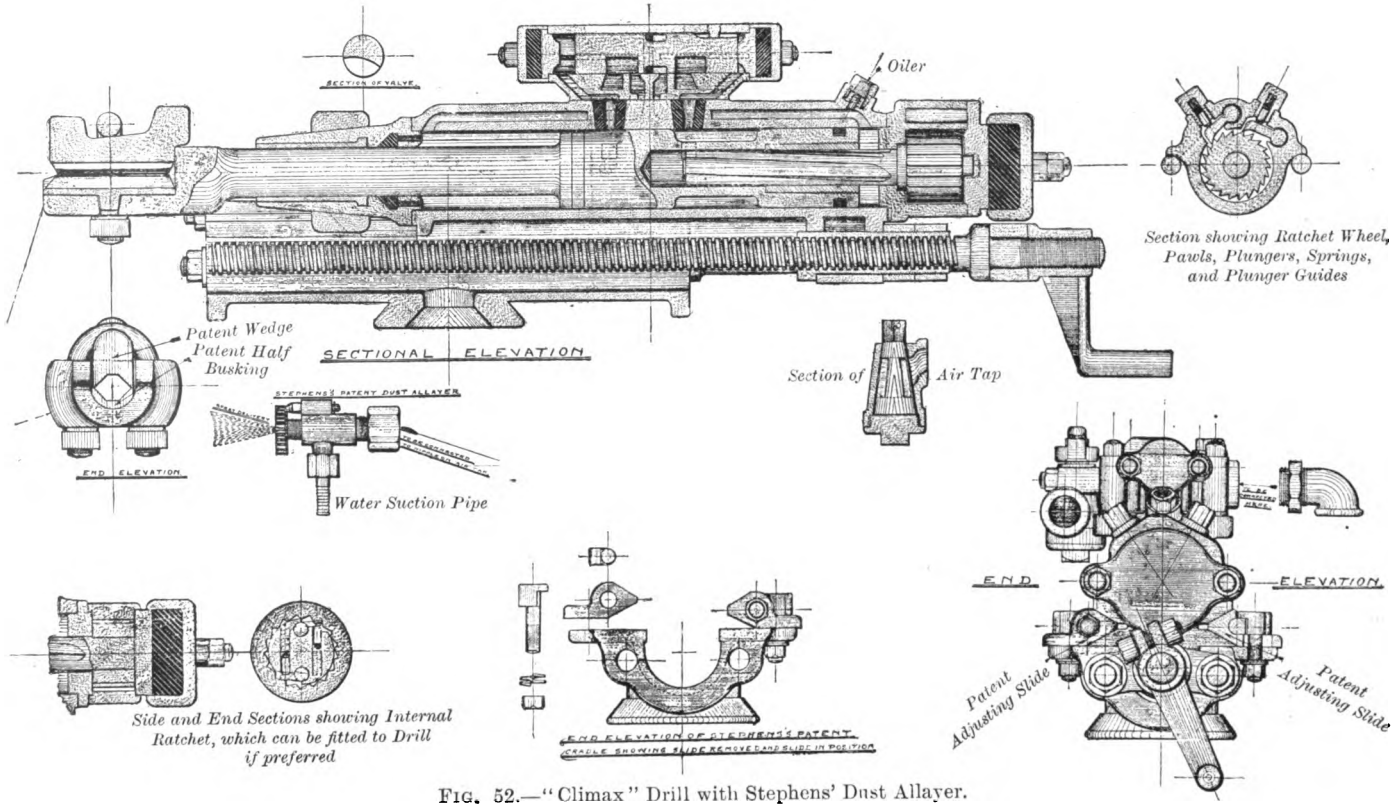

SECTION OF VALVE
Oiler
Section showing Ratchet Wheel, Pawls, Plungers, Springs, and Plunger Guides
Patent Wedge
Patent Half Bushing
SECTIONAL ELEVATION
Section of Air Tap
END ELEVATION
STEPHENS' PATENT DUST ALLAYER
Water Suction Pipe
Side and End Sections showing Internal Ratchet, which can be fitted to Drill if preferred
END ELEVATION OF STEPHENS'S PATENT CRADLE SHOWING PIPE REMOVED AND SLIDE IN POSITION
END
ELEVATION
Patent Adjusting Slide
Patent Adjusting Slide

FIG. 52.—"Climax" Drill with Stephens' Dust Allayer.

worked without water being first conveyed to the bottom of the hole.

Drill Holder.—The same firm have designed a remarkably simple and efficient form of drill holder (see Fig. 53), which consists of a U-bolt (*a*), two nuts (*c*), and a wedge piece (*b*). The wedge, it will be seen, is a combination of wedge and gripping pad,

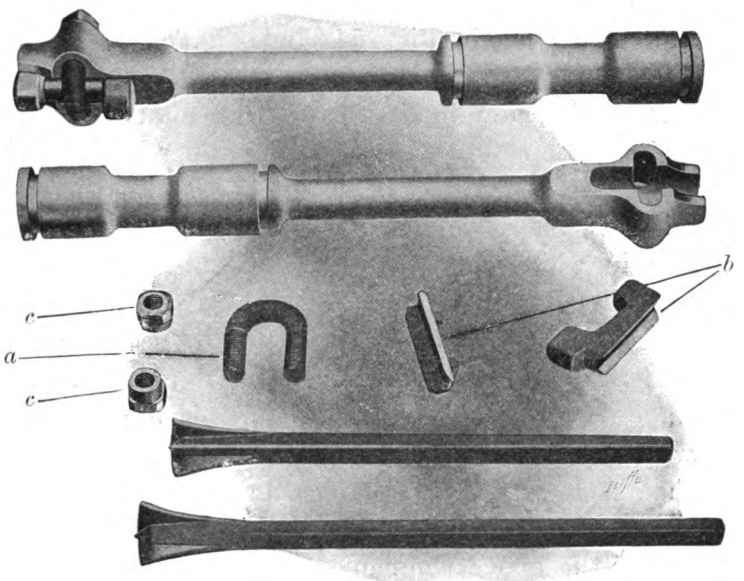


FIG. 53.—Stephens' Drill Attachment.

and directly grips the boring bit, a tap with a hammer being sufficient to loosen the wedge when it is desired to insert a fresh bit, after which the wedge is pushed forward by hand, and the first blow by the machine automatically tightens the wedge of the borer. The longer bearing surface of the newer gripping pad, $5\frac{1}{2}$ inches as against $2\frac{1}{4}$ inches in the former types of U-bolt head, is a great advantage.

Pneumatic Hammer Drills.—A type of this drill

as manufactured by the Hardy Patent Pick Company is shown in Fig. 54. It consists of a cylinder in which is caused to reciprocate by compressed air a hardened steel hammer or piston, which strikes on a steel drilling tool 1500 to 2000 times per minute, the nature of the valve motion allowing this high speed without cushioning. The machine reproduces, it will be observed, the action of hand drilling by means of hammer and drill. The parts are explained in Fig. 54, and Fig. 55 shows the manner of applying this drill when sinking. The valve is of D section and is air-thrown, the rotation of the drill being effected by means of a rifle bar working in a twist nut in the piston or hammer, the first portion of which is made square, and consequently revolves the part in which the drill steel is situated.

The following particulars relative to the work performed by a hammer drill recorded by M. Ledouble, one of the Belgian Inspectors of Mines, are of interest. The drill in question was the François pneumatic hammer, and was used in the Charbonnages Réunis de Charleroi. The hammer weighs 7·7 kilogrammes, delivers 2500 blows per minute, and has enabled—at the Hamendes Colliery of the above company—a hole 36 mm. in diameter to be driven in soft sand or shale at the rate of 0·22 mm. per minute. The cost of working during the test period of sixty-eight days, or, eliminating the time taken to prepare the working, of fifty-six days, was 13,383·53 fr., comprising the following items:—Wages of drill-men and assistants, 4940·35 fr.; inspection, 989.50 fr.; tram men and hauliers, 2051·50 fr.; fodder for one horse, 200 fr.; explosives, 2530·45 fr.; installation of portable engine, 600 fr.; expenses at bank, repairs, engine-men, &c., 1639 fr.; repairs to picks and drills, 432·73 fr. The cost per running

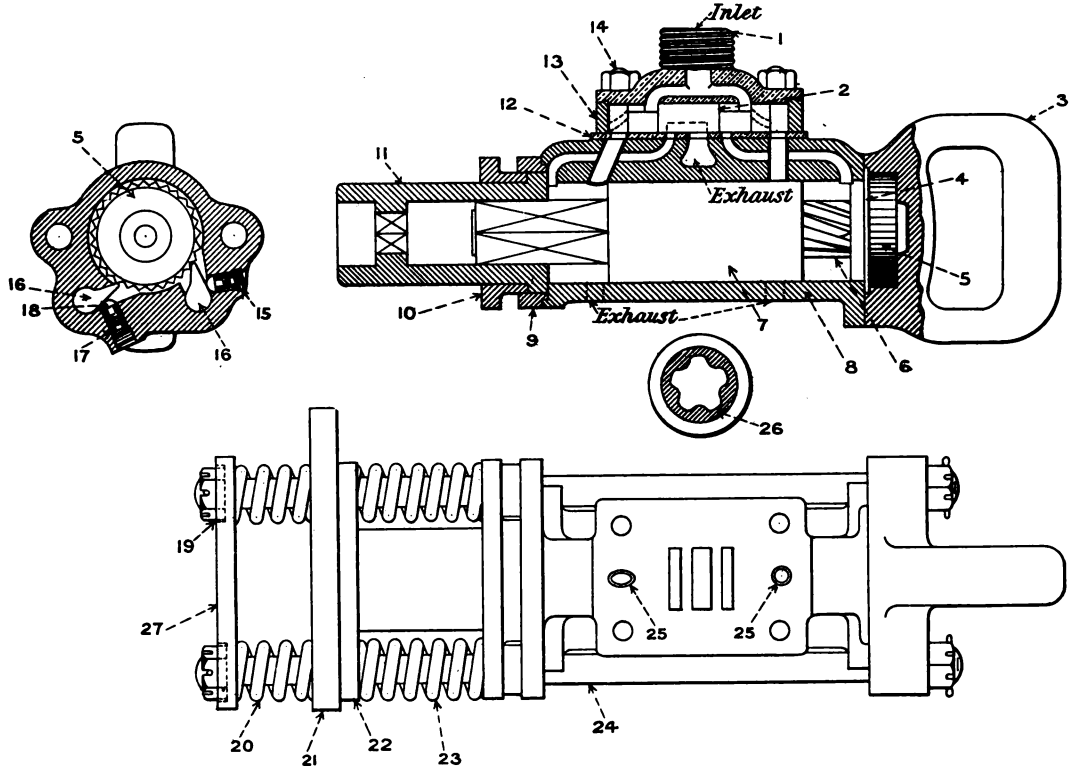


FIG. 54.—Details of the "Hardy Simplex" Sinking Drill.

1. Valve Box.
2. Valve.
3. Handle and Cylinder Back
4. Rifle Bar Plate. [Cover.
5. Ratchet Wheel.
6. Rifle Bar.
7. Piston.
8. Cylinder.
9. Cylinder Cover.
10. Auxiliary Cylinder Cover.
11. Drill Chuck.
12. Valve Plate
13. Valve Box End Cover.
14. Set Screw, for Valve Box.
15. Screw.
16. Pawl.
17. Spring.
18. Plunger.
19. Buffer Spring Nut.
20. Buffer Spring (Short).
21. Back Chuck Plate.
22. Chuck Support Plate.
23. Buffer Spring (Long).
24. Side Bolts.
25. Valve Tube.
26. Rifle Bar Twist Nut.
27. Front Chuck Plate.
— Large Central Buffer Spring (Replaces No. 23)
— Spring Cotter for No. 21, with Chain.
— Inlet Cock and Coupling.

metre was 82·77 fr., to which has to be added the cost of compressed air. The rate of advance was 2·60 m.

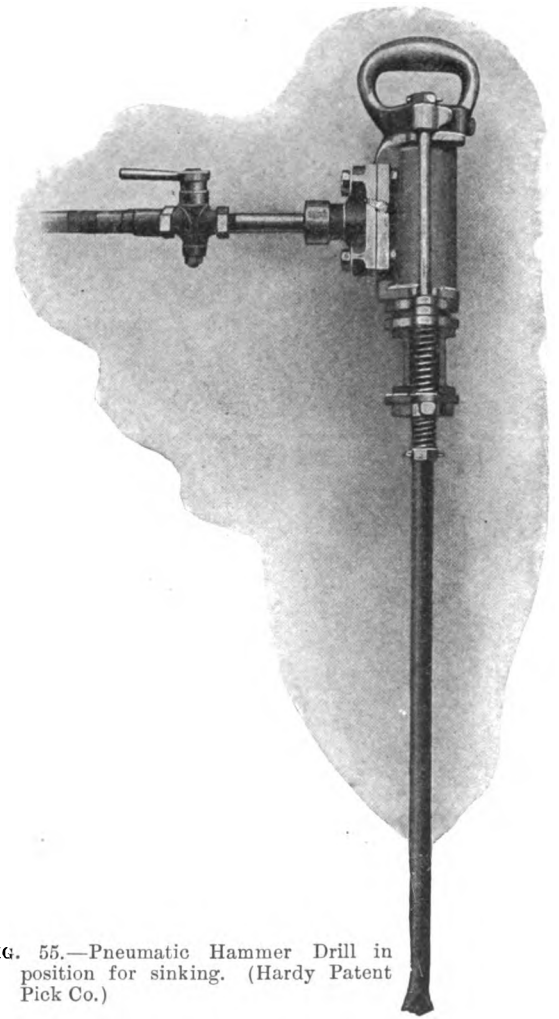


FIG. 55.—Pneumatic Hammer Drill in position for sinking. (Hardy Patent Pick Co.)

per day, or, approximately, 3 m. per day in shale, and 1·80 m. to 2 m. in hard strata.

Rate of Drilling. Comparative Efficiency of Hand and Machine Drilling.—It is difficult to

obtain sufficiently extensive and reliable data from which to strike an accurate average of the work performed by power-driven rock drills, when sinking colliery shafts, as, until recently, the great majority of such shafts have been sunk by means of hand drilling; but in the case of metalliferous mines the much harder nature of the rock which has usually to be penetrated when sinking the shafts necessitates the use of power drills, and numerous examples are forthcoming as to the high efficiency of the different types of power drills used under these conditions; yet we have it on the authority of Mr. A. E. Pettit,[1] that in the case of the shafts sunk on the Rand the rate of progression and the condition of the finished shafts which have been "machine sunk" do not equal those which have been "hand sunk," and he states that the general consensus of opinion on the Rand certainly "trends to hand sinking in the future"; although the rocks sunk through in these cases are peculiarly hard and often semi-crystalline. Mr. Frank Coulson, on the other hand, alluding to colliery shafts, says:[2] "It is no uncommon experience for three men to drill six holes with two machine drills during the time that twelve men are drilling four holes by hand; the special advantage in favour of the use of rock drills in hard stone being that the same work is effected in about half the time."

Number and Position of Drill-holes at the Bottom of the Shaft.—As Mr. Coulson remarks:[3] "In order to obtain the greatest advantage from the use of rock drills in sinking or tunnelling, it is necessary that a given length be driven by each series of holes,

[1] "Sinking, Development, and Underground Equipment of Deep-level Shafts on the Rand," by Arthur E. Pettit, *Trans. Inst. M.M.*, vol. xv. pp. 333–366.

[2] "Sinking with Rock Drills," by Frank Coulson, *Trans. Inst. M.E.*, vol. viii. p. 19.

[3] *Ibid.*, pp. 18, 19.

and that all the holes of such series should be fired simultaneously, either by electricity or by a quick-running fuse; but there is some danger in using the latter. Not only where rock drills are used, but where the holes are drilled by hand, much better results are obtained in all cases by firing all the holes at once by electricity."

The number of holes to be drilled at the shaft bottom is important. This varies, of course, according to the nature of the rock being sunk through. Again quoting from the above eminent authority: "In hard limestone or very hard sandstone, as the Pennant Rock[1] of South Wales, there should be about nine sumping-holes about $4\frac{1}{2}$ feet deep, and from about twenty to twenty-two canch-holes round the sides, each about 4 feet deep. In ordinary sandstone, probably nine sumping-holes about 6 feet deep, and from eleven to thirteen canch-holes 5 feet deep, will be sufficient. In shale or mild sandstone, nine sumping-holes drilled to a depth of about $6\frac{1}{2}$ feet will clear out 6 feet of stone, leaving the sides perfectly perpendicular, or at most requiring two or three additional canch-holes, which are put in by hand during the time that the loose stones are being sent out of the pit.

"Where both sumping and canch holes are drilled, the sumping-holes are fired first, an iron rod, with a loop on top, being put into each canch-hole to prevent them from being filled up by loose stones from the shots. While the workmen are filling away the stones from the sumping-holes, the canch-holes are being charged, and are fired at the most suitable opportunity.

[1] The Pennant grit series comprises a number of hard sandstones which surmount the lower Coal-Measures in the South Wales coalfield; of these the "Cockshot Rock" is the most prominent, and is sometimes designated "Pennant Rock."

When no canch-holes are required, all the sumping-holes are fired together."

Figs. 56 and 57 show an efficient arrangement of the shot-holes at the bottom of a shaft of from 18 to 20 feet in size. In Fig. 56 the positions of the nine sumping-

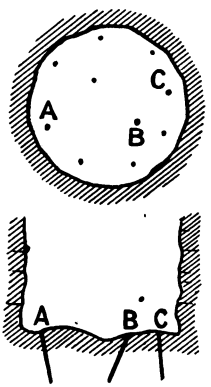


FIG. 56. — Position of Sumping-Holes at Bottom of a Shaft.

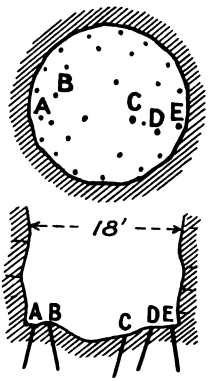


FIG. 57.—Position of Sumping and Canch Holes at Bottom of a Shaft.

holes, 4½ feet deep, are indicated, and in Fig. 57 both the sump-holes and twenty canch-holes, 4 feet deep, are shown.

The rate of drilling each round of these holes by machine rock drills would be, according to Mr. Coulson—

In hard limestone	4½ feet in 18 hours
In hard sandstone	5½ ,, ,, 18 ,,
In shale and sandstone . . .	6½ ,, ,, 16 ,,

and the average quantity of gelignite used would be—

In hard stone for a length of 4½ to 5 feet—	
Nine sumping-holes, 3 lbs. each . . .	27 lbs.
Twenty canch-holes, ¾ lb. each . . .	15 ,,
Total	42 lbs.
In millstone, for a length of 6 feet—	
Nine sumping-holes, 3½ lbs. each . . .	32 lbs.
Eight canch-holes, ¾ lb. each	6 ,,
Total	38 lbs.

This large quantity of explosive is used not only to lift but to break the stone, and so save labour.

The weight of stone lifted with each round of shot averages—

In hardstone	130 tons
In millstone	155 ,,

The following results in point of cost are given by Mr. Coulson: [1]—

Average Cost per Week, the Rate of Wages being that prevailing in the North of England, May 1894.

	Depth sunk. Feet.	Cost per yard. Wages. £ s. d.	Explosives. £ s. d.	Total. £ s. d.
Very hard limestone, without partings . .	30	10 4 9	1 18 0	12 2 9
Coal-Measure shales, and sandstones . . .	30	7 12 6	0 19 0	8 11 6

Fig. 58 shows the arrangement of shot-holes in a rectangular shaft.

In the Charters Towers gold-mining region of Queensland, sinking of shafts is to a great extent carried on by means of power drills. For instance, Day Dawn Freeholds Consolidated may be taken as typical of the best practice in granite "country." [2] The shaft is $15\frac{1}{2}$ feet by 4 feet in the clear, and the excavation in the granite was roughly 18 feet by $6\frac{1}{2}$ feet. Two pairs of Ingersoll-Sergeant drills, using $1\frac{1}{4}$ inch steel, were clamped on two stretcher bars—a pair on each bar—and 32 to 36 holes were disposed in a manner similar to that shown in Fig. 58. The time occupied in drilling was 4 hours and 30 minutes, the remainder of an 8 hour shift being occupied in rigging the machines.

[1] "Sinking with Rock Drills," by F. Coulson, *Trans. Inst. M.E.*, vol. viii. pp. 17–24.

[2] "Report to the Government of Queensland," by J. Malcolm Maclaren, B.Sc., Assistant Government Geologist, 1901.

The next shift was consumed in charging and firing the "centre cut" or "sumping" (1 to 8) holes, and by the end of the third shift the whole of the work had been done, and the shaft bottom was ready with a clean surface for the next shift. The average rate of progress was 5 feet 8½ inches per complete "round" or "sink." The record (claimed to be a record for all

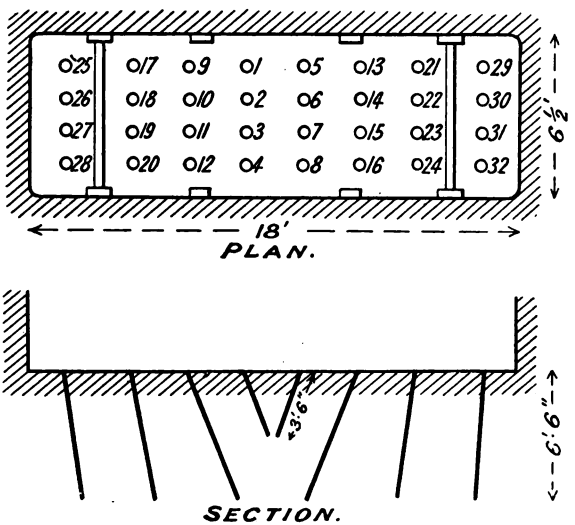


FIG. 58.—Arrangement of Shot-holes at the Bottom of a Rectangular Shaft.

Australia also) for this shaft was 137 feet sunk per month; the average rate of sinking per month over the whole depth of the shaft being 94 feet. Blasting gelatine was used, at an average cost per foot of £8.

Rotary (Diamond) Drilling.—When sinking Harris' Deep Navigation Colliery, South Wales, great difficulty was found in penetrating the Pennant Rock, owing to its excessive hardness, so when the North Pit was 178 yards, and the South Pit 200 yards from the surface, a contract was made in July 1875 with the Diamond

Rock-boring Company, to sink through this rock. Eight drills were at first used, and afterwards from thirty to forty shot-holes were bored from three to five feet deep, occupying about twelve hours. These were then fired in this order—first, the sump-holes, then the bench-holes, and finally, the side holes. The progress was very slow, being only at the rate of seven feet per week. But after several changes in the arrangement of the holes, the use of the diamond drills was finally abandoned, owing to the great cost in diamonds, and the contract was finished with the Beaumont percussion drill. The depth sunk under contract was, North Pit, 69 yards, and South Pit, 56 yards. The later stages of the sinking were carried out with the Ingersoll drill.

Explosives.—All explosives exert an equal force in every direction, but an explosive *takes effect* along the line of least resistance. In a homogeneous material this will be the shortest line from the charge to the face, and will be most efficient when it is at right angles to the line of the shot-hole, and least efficient when it coincides with the axis of the shot-hole. The quantity of the explosive that should be used varies as the cube of the line of least resistance.

Although nitro-glycerine was discovered in 1846 by Ascanio Sobrero, Professor of Chemistry at Turin, and in 1866 Nobel found a suitable absorbent (*Kiesl-guhr*), and in the year following introduced dynamite (nitro-glycerine and the absorbent), yet until about thirty years ago gunpowder was practically the only explosive employed in mining operations.

At the present time the explosives ordinarily used in mining may be divided into six main groups, viz.—

1. *Gunpowder* (*e.g.* blasting powder and other gunpowders).

2. *Nitro-cellulose* (*e.g.* gun-cotton, tonite).

3. *Nitro-glycerine* (*e.g.* gelignite, dynamite, carbonite.)

4. *Nitrate of ammonia* (*e.g.* ammonite, bellite, roburite).

5. *Chlorate of potassium* (*e.g.* rack-a-rock).

6. *Fulminate of mercury* (mainly used for detonators).

For the purpose of sinking shafts, gunpowder and gelignite are perhaps most commonly used.

Gunpowder is composed of saltpetre, carbon, and sulphur; but mining powder contains rather less saltpetre than that used for sporting or military purposes.

Mr. Oscar Guttmann[1] gives the following Table of composition of blasting powder in different countries:—

TABLE VI.—*Composition of Blasting Powder in different Countries.*

Ingredients.	Great Britain.	Germany.	Austria-Hungary.	France.	Russia.	Italy.
Saltpetre . . .	75	70	60·19	72	66·6	70
Sulphur . . .	10	14	18·45	13	16·7	18
Charcoal . . .	15	16	21·36	15	16·7	12

A cartridge of mining powder 1 inch in diameter and 38 inches long contains one pound of powder. Gunpowder explodes at a temperature of 482° Fahr., and expands to 1500 times its original volume—or, to express the fact in another way, at a barometric pressure of 760 mm. and a temperature 0° C., the volume of the permanent gases generated by the explosion of 1 gramme of dry mining powder is 360·3 cubic centimetres, and that of nitro-glycerine 500 c.c.

The chemical change that takes place on the ex-

[1] *Blasting*, by Oscar Guttman, M.Inst.C.E., F.I.C., F.S.S., p. 15.

ploding of gunpowder may be represented by the equation :—

Sulphur.	Carbon.	Saltpetre.	Carbonic acid gas.	Nitrogen.	Potassium sulphide.
$2S$	$+ 3C +$	$2KNO_3 =$	$3CO_2$	$+ {}_2N +$	$2KS$

Gunpowder is cheaper and slower in action than the so-called higher explosives, and on account of the latter quality is better suited for blasting soft rocks than are those explosives which are possessed of greater rending power.

Gelignite consists of 65 parts of gelatine and 35 parts of absorbent, the chemical constitutents being as follows :—

Gelatine	Nitro-glycerine . . .	62·56	per cent.
	Collodion cotton . . .	2·50	,,
Absorbing powder .	Saltpetre	26·25	,,
	Wood pulp	8·40	,,
	Soda	0·35	,,
		100·00	,,

Blasting Gelatine usually consists of 92 parts of nitro-glycerine to 8 of collodion cotton. The chemical result of the explosion of a charge of nitro-glycerine may be expressed as follows :—

$$2C_3H_5(NO_3)_3 = 6CO_2 + 5H_2O + 6N + O.$$

A blow from a hammer on a thin layer of nitro-glycerine explosive laid on a hard surface is sufficient to explode it. As in cold weather these explosives freeze and become hard, and are then more liable to the effects of concussion, the makers provide warming pans for thawing the cartridges and keeping them in a plastic state.

The Care and Use of Dynamite Compounds.—The following instructions in the care and use of dynamite, gelignite, gelatine-dynamite, and blasting gelatine

are compiled from directions which have been issued from time to time by Messrs. Nobel.

Unlike gunpowder—dynamite, blasting gelatine, and gelatine-dynamite require a special mode of firing, which consists of a very strong percussion cap, called a "detonator," which is attached to a Bickford fuse. The fuse explodes the fulminate, which then explodes the cartridge.

A charge is made as follows:—

1*st Operation.*—A proper length of safety-fuse is cut clean across immediately before using, the sawdust shaken out of the detonator, which is then slipped

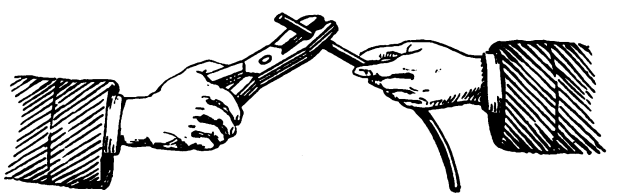


FIG. 59.—Preparation of a High-explosive Shot. 1st Operation.

over the end of the fuse till it reaches the fulminate. The upper part of the cap is then gently but firmly squeezed with a pair of nippers (as shown in Fig. 59). The detonator should not be screwed or twisted on to the safety-fuse, as all friction should be avoided. It is well to cut the free end of the fuse slantwise to facilitate lighting; and for use under water, or wet work generally, great care should be taken to have the upper end of the detonator made water-tight (with grease, tar, or otherwise) where it joins the fuse, to prevent the fulminate from getting damp.

2*nd Operation, or Preparation of the "Primer" Cartridge.*—A hole is made in one end of a cartridge with a small stick, and the detonator, with the fuse

already attached to it, is pushed in so as to leave about one-third of the copper tube exposed outside the cartridge. When blasting by electricity, the detonator

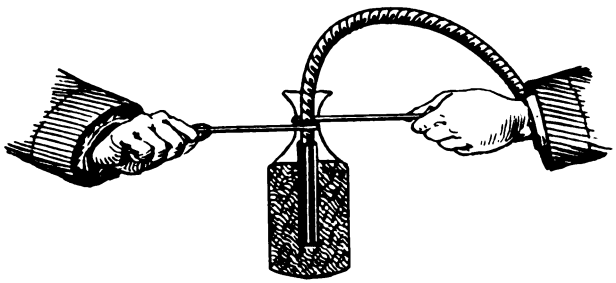


FIG. 60.—Preparation of a High-explosive Shot. 2nd Operation.

should be completely buried in the explosive cartridge, and the cartridge paper attached to the wires of the detonator. The detonator is then securely tied in that position (Fig. 60). If the detonator is pushed too far

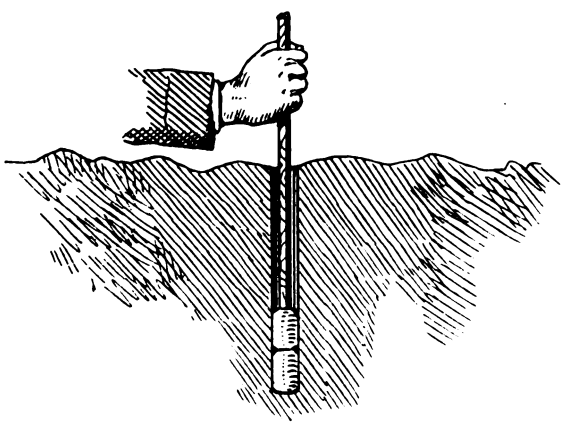


FIG. 61.—Preparation of a High-explosive Shot. 3rd Operation.

into the cartridge, the fuse may set fire to the latter before the spark can explode the detonator, and unpleasant fumes may be the consequence.

3rd Operation.—The bore-hole is cleaned out, and the cartridges inserted one at a time, and each gently squeezed home with a wooden rod (as shown in Fig. 61). Iron should never be used in squeezing home cartridges; nor should the cartridges be bunched or doubled. They can always be supplied to fit any bore-hole.

4th Operation.—Over the charge, as shown in the third operation, the primer cartridge, *i.e.* the cartridge

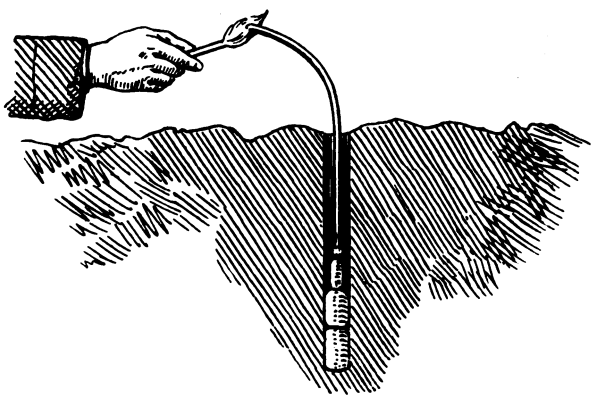


FIG. 62.—Preparation of a High-explosive Shot. 4th Operation.

with detonator and fuse affixed, is inserted, and *very gently* pushed into the hole until it rests against the charge. Sand or clay is then put in as tamping, several inches loosely before beginning to ram hard. The charge is then ready for firing (Fig. 62).

Treatment of Dynamite, Blasting Gelatine, and Gelatine-Dynamite in Cold Weather.—In cold weather these explosives become hard or frozen, and lose their plastic or soft condition, but thaw and resume it when warmed.

Accidents have occurred through warming cartridges

on or before stoves and fireplaces; this is highly dangerous, for these explosives, when slowly heated to 420° Fahr., are liable to explode with great violence.

Frozen cartridges are easily safely thawed, and made to resume their plastic condition by putting them into an empty water-tight tin can, which should then be placed in a vessel of hot water, till the cartridges have resumed their normal condition.

The temperature of the water should not exceed 130° Fahr.

Special portable warm-water heating pans are made, wherein the cartridges are kept warm and in a soft, plastic state for several hours in the coldest weather.

In tropical countries, open boxes of dynamite, blasting gelatine, and gelatine-dynamite should never be exposed to the direct rays of the sun.

The foregoing instructions for charging holes, and for treatment in cold weather, apply equally to dynamite, blasting gelatine, and gelatine-dynamite.

Epitome of Instructions and Cautions which should be observed by Users of Dynamite, Gelignite, Blasting Gelatine, and Gelatine-Dynamite, &c.

1. A wooden rod or squeezer should be used to push home the cartridges in the bore-hole. Never use a metal rod or rammer.

2. Never ram or pound the charge home. It should be gently, although firmly, squeezed into its place.

3. Never squeeze the primer containing the deto-

nator; but lower or push it gently, until it rests on the charge.

4. If a miss fire occurs, a second hole should be bored at a safe distance from the first, and in such a direction as will keep the boring-tool clear of the first hole. After firing the second hole, the débris should be thoroughly searched for the unexploded cartridges.

5. A miss-fired hole should never be touched.

6. When blasting with safety-fuse a miss-fired hole should not be approached until a safe time has elapsed.

7. In charging wet holes, care should be taken to ascertain that the cartridges are squeezed well home, and that they rest on each other.

8. If the cartridges are not pressed well down, water may come between them, and prevent the explosion of the primer or cartridge containing the detonator from communicating to the other cartridges.

9. In such a case, when the primer is exploded, the operator may be deceived by the sound, and think that the charge has completely exploded; whereas the layer of water may have prevented the transmission of explosion throughout.

10. If the hole is not then carefully examined, some dynamite may remain in it, and prove a source of accident in boring the next hole.

11. All holes that appear insufficiently blasted must be carefully searched with a wooden rod, to ascertain whether any dynamite remains in them after the explosion. Accidents have occurred from neglect of this precaution.

12. All wet holes ought to be blasted as soon as possible after charging.

13. It is highly dangerous to place these explosives on or near fires, stoves, steam-pipes, or any highly heated metal. Dynamite must never be put into warm water to thaw or soften. It ought always to be put

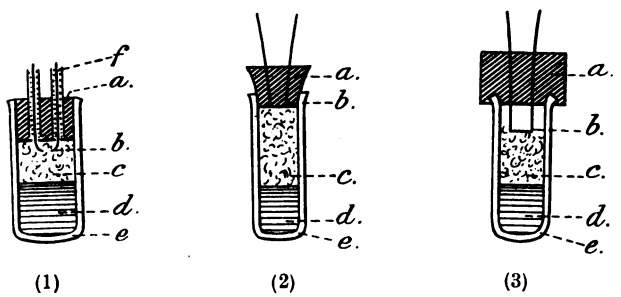


FIG. 63.—(1) Slot Detonator; (2) Bridge Detonator; (3) Incandescent Detonator.

(*a*) Indiarubber; (*b*) Brass; (*c*) Antimony Sulphide and Potassium Chlorate forming the Priming Mixture; (*d*) Fulminate of Mercury; (*e*) Copper Casing; (*f*) Mixture of powdered Glass and melted Sulphur.

In (2) the terminals are filed off flush with the inside of the plug of indiarubber and a line drawn with a pencil for the path of the electric current, which gives many sparking points.

In (3) a fine platinum wire connects the ends of the brass lines.

first in a water-tight vessel, and then have that vessel placed in the warm water.

14. Cartridges, when frozen, may be softened without danger in warming pans, such as the company supply for the purpose.

15. These explosives should never be exposed to the direct rays of a tropical sun.

Fuse.—The fuse most commonly used is that known as Bickford's (No. 1831), which consists of a thin thread of powder spun round with jute yarn and waterproofed. A good fuse burns at the rate of about one foot in thirty seconds.

Detonators. — The higher explosives are exploded by detonation. The detonators used consist of small copper cylinders closed at one end, and containing fulminate of mercury with a small proportion of chlorate of potassium as a priming mixture. Detonators are commonly designated as being of high or low tension, and are of three types, viz. the slot detonator (Fig. (1) 63), requiring a high-tension electric current to fire it; the bridge detonator (Fig. (2) 63), and the incandescent detonator (Fig. (3) 63), requiring for its explosion a current of considerable intensity, though of low tension, hence a powerful electro-magnetic apparatus is necessary to generate the current to fire a large number of the latter. In the high-tension detonators the explosion is caused by the electric current heating the chemical compound to ignition-point; whereas in the low-tension detonator the explosion is due to the iridio-platinum wire bridge becoming red-hot and firing the priming. The circuit in low-tension detonators can be tested before being taken into the pit by means of a galvanometer, the detonator being placed in an iron pipe or box during the process in case the fuse is accidentally fired (Fig. 65).

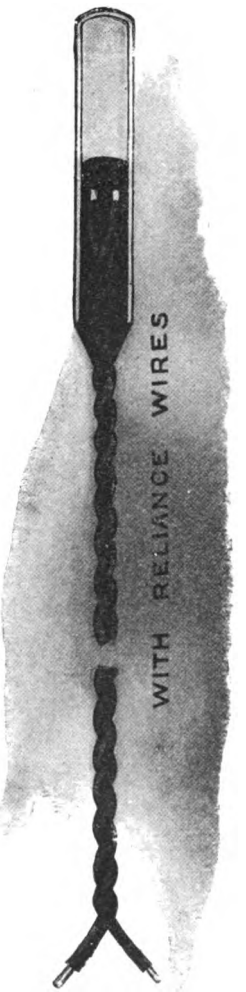


FIG. 64.—Detonator used for Blasting in Mines. (Hardy Patent Pick Co.)

Stemming and Firing Charges.—The hole having been drilled as cylindrical as possible, is cleaned out with

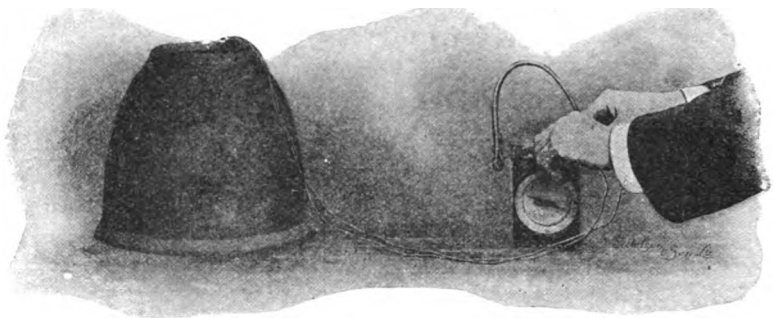


FIG. 65.—Method of Testing the Circuit of Low-tension Fuses (Detonators) before the same are taken into the pit.

a scraper (*a*), Fig. 67, the cartridge placed at the end of a pricker (*b*), composed of some material which cannot strike fire—usually some alloy of copper—and gently lowered into the bottom of the hole, and then carefully

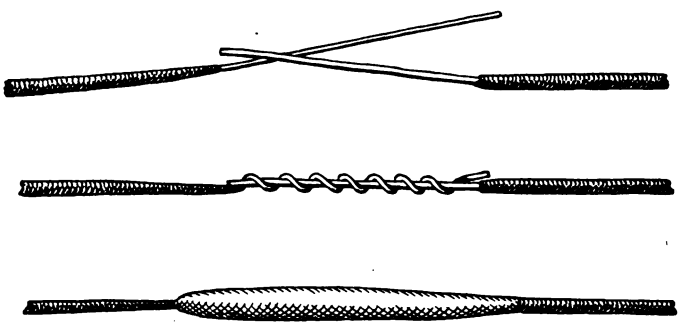


FIG. 66.—Manner of connecting Detonator and Cable Wires.

stemmed with clay or stone-dust tamping; a tamping rod or stemmer composed of an alloy similar to that of the pricker, or, if the explosive is of the nitro-glycerine

order, of hard wood, being used. The tamping should be very gently performed, especially at the outset, if the hole is charged with a high explosive. On the completion of

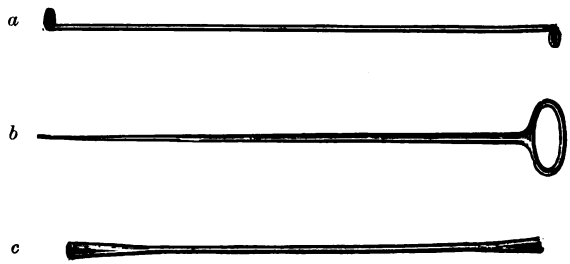


FIG. 67.—(*a*) Scraper; (*b*) Pricker; (*c*) Tamping Rod or Beater.

the stemming the pricker is carefully withdrawn and the fuse inserted. If a high explosive, which is fired by means of detonation, is being used, then a pricker is not required (unless to lower the charge with detonator into the hole). With gelignite as the explosive, water may be used as stemming, if the direction of the shot-hole allows of it.

Electric Blasting.—Magneto exploders (Figs. 68 and 69), whether high or low tension, are similarly constructed, the only difference being that the former are wound with finer wire than the latter. Battery exploders, which are used for low-tension fuses only, may consist of several primary batteries in a case with connecting terminals.

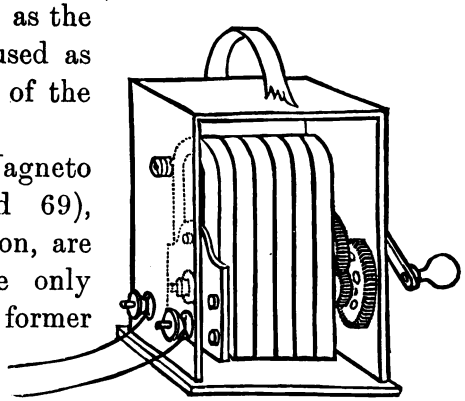


FIG. 68.—Magneto Exploder (old type). (John Davis & Son, Ltd.)

Having tamped the hole, the electric wires should be

carefully connected up, first having separated and cleaned the ends of the fuse wires and firing cable by twisting them together, and seeing that the lead and return wires are not touching each other. When the end of the cable is reached, which will be either at the surface or in some safe recess in the shaft, the ends of the firing cable are connected to the terminals of the exploder, the

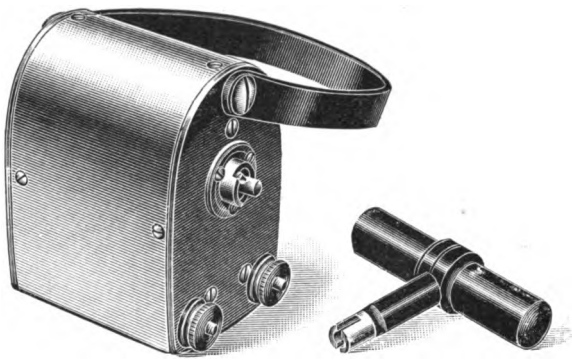


FIG. 69.—The "Davis Derby" Magneto Exploder.
(John Davis & Son, Ltd.)

machine is steadied with the left hand, the handle being sharply turned with the right, and after a moment or two the button pressed whilst still working the handle.

In the "Davis Derby" exploder (Fig. 69) the tedious process of revolving a cranked handle and pressing a button is displaced by a handle which works on a shaft supplied with a ratchet in front of the gear wheel. The detachable handle is placed into the socket and requires to be quickly revolved until it has made one half turn, so making the contact automatically.

CHAPTER IV

THE PROCESS OF SINKING AND LINING SHAFTS—TEMPORARY SUPPORTS—WALLING AND TUBBING

LET it be supposed that the shaft, one of a pair which are to open out a colliery, is to be 18 feet in diameter when walled, and 400 yards in depth. Having determined the position, a stake will be driven into the ground as a centre, and the circle of the shaft marked out from it. The sinking and temporary supporting is then carried out in the following manner:—

Setting out the Shaft.—The circle is struck with a diameter 2 feet greater than the net size of the shaft when walled. Forming a square about the surface of the shaft are laid the heavy sills or hanging balks (*aa*, Fig. 70), which constitute in some cases, also, the foundation for the shear legs and carry the rail track (Fig. 71) along which the landing trolley passes over the mouth of the shaft for receiving the kibble when laden with men, débris, or water from the shaft, and when the men are about to get into the kibble to descend the shaft. Folding doors, such as are shown in Fig. 72, may be, and commonly are, used to serve the same purpose.

The excavated matter is teamed about the mouth of the shaft or conveyed by tip trucks running on a tramway to a dump heap some distance off.

The axis of the shaft is kept rigorously vertical by means of a centre and side plumb-lines; the side

plumb-lines being always in position except when shots are about to be fired, and the centre line occasionally hung as a check.

Temporary Side Supports.—For the purpose of protecting the sides until the rock-head is reached, cribs of oak 4 inches square, made in sections as shown

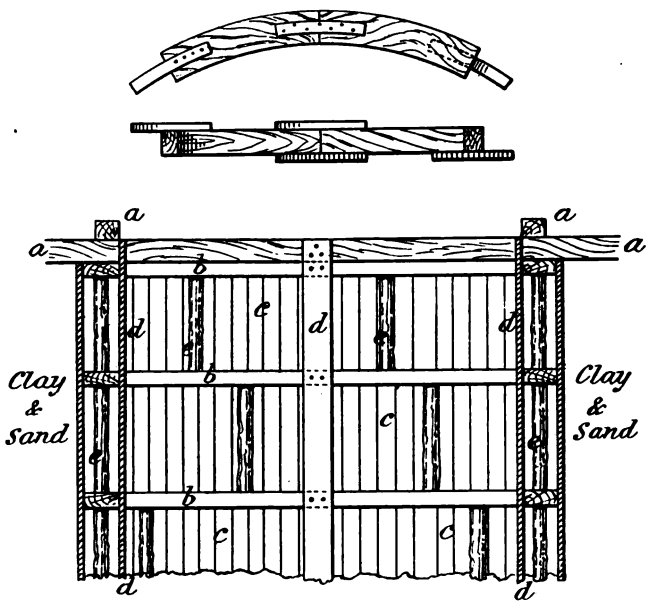


FIG. 70.—"Cribbing," or Temporary Lining of Shaft.

in Figs. 70 and 73, are used. The size of such cribs depends, of course, on the diameter of the shaft and the amount of pressure they have to resist, but from 4 to 6 inches square are the usual sizes under average conditions when constructed of oak. The cribs (or curbs, as they are sometimes called) are usually placed every 3 feet apart; the manner of placing them being as follows:—The shaft is sunk to a depth of 6 feet, and a crib laid on the bottom, which is first accurately dressed to

ensure absolute horizontality, after which another 6 feet of clay is taken out, the sides of the pit being in a line with the inside of the first crib; the sides at the bottom of the pit—that is, at 9 feet from the surface—are then shorn out to allow of a second crib being laid, which being done, the sides are also shorn out upwards, and when the first crib is reached it is held in position, as its foundations are being removed, by punch props. Behind these two cribs backing deals in 9 feet lengths are forced, and a third crib, half-way intermediate between the surface and that first laid, is placed in position and supported by punch props, and a fourth crib at the surface, resting on punch props. Stringing deals are then suspended from the surface staging and nailed to the cribs. This process of temporarily supporting the side is continued until the stone-head is reached, when the shaft is continued in line with the inside of the last crib for some little distance before being widened out to its gross diameter, and so sunk until hard and firm stone is reached, such as is suitable for the formation of a walling bed. This being found, the sides are cut back to allow of the placing of a cast-iron crib (curb or garland) of the section and dimensions shown in Fig. 81, or, sometimes, as shown in Fig. 80. The bed having been accurately dressed and its horizontality tested by spirit-level, on it are placed the segments of the walling curb (see Figs. 73, 80, and 81), and fir sheathing being inserted

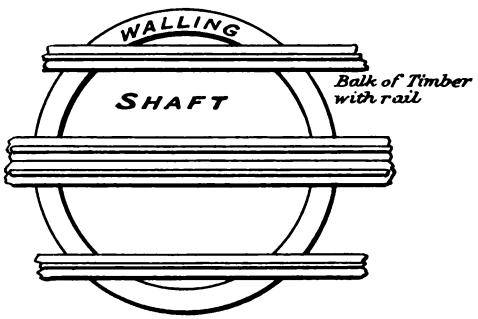


FIG. 71.—Manner sometimes adopted of laying Rails across the Surface of a Shaft.

between the joints of the segments, the whole is tightened up by forcing in wedges at the back between the curb and the side of the shaft. On this the cylinder

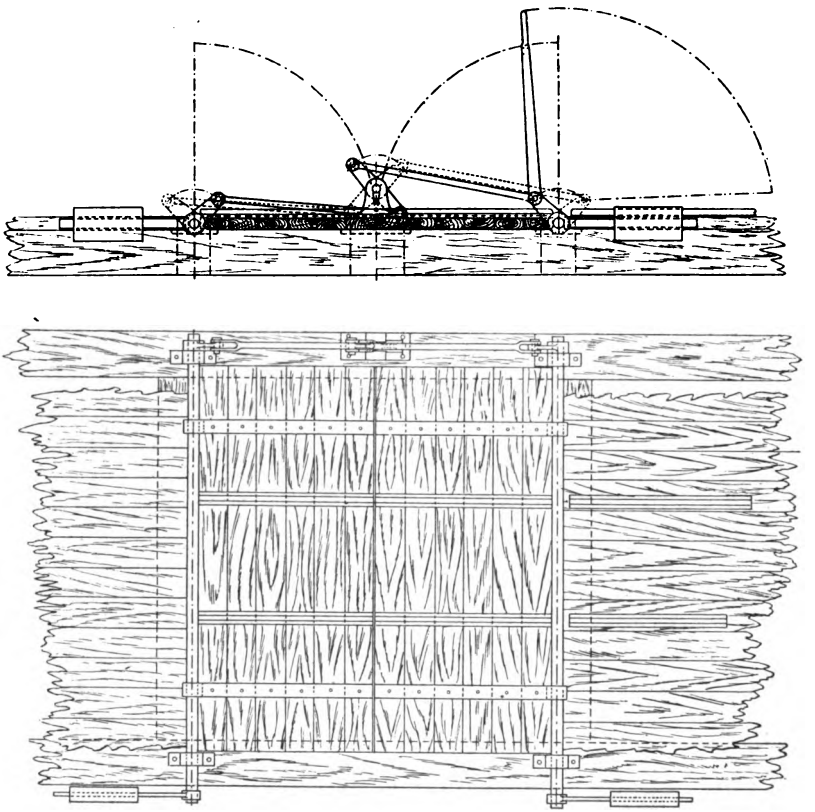


FIG. 72.—Plan and Section of Doors for Covering the Top of a Sinking Pit. (Messrs. J. Cook, Sons & Co., Ltd.)

of walling is erected. Sometimes the segments of the curb are joined by being bolted together, usually eight of them forming the circle.

Fig. 73 shows the details of temporarily supporting the sides of a shaft with wood in the manner described, and of erecting the permanent brick walling in the case

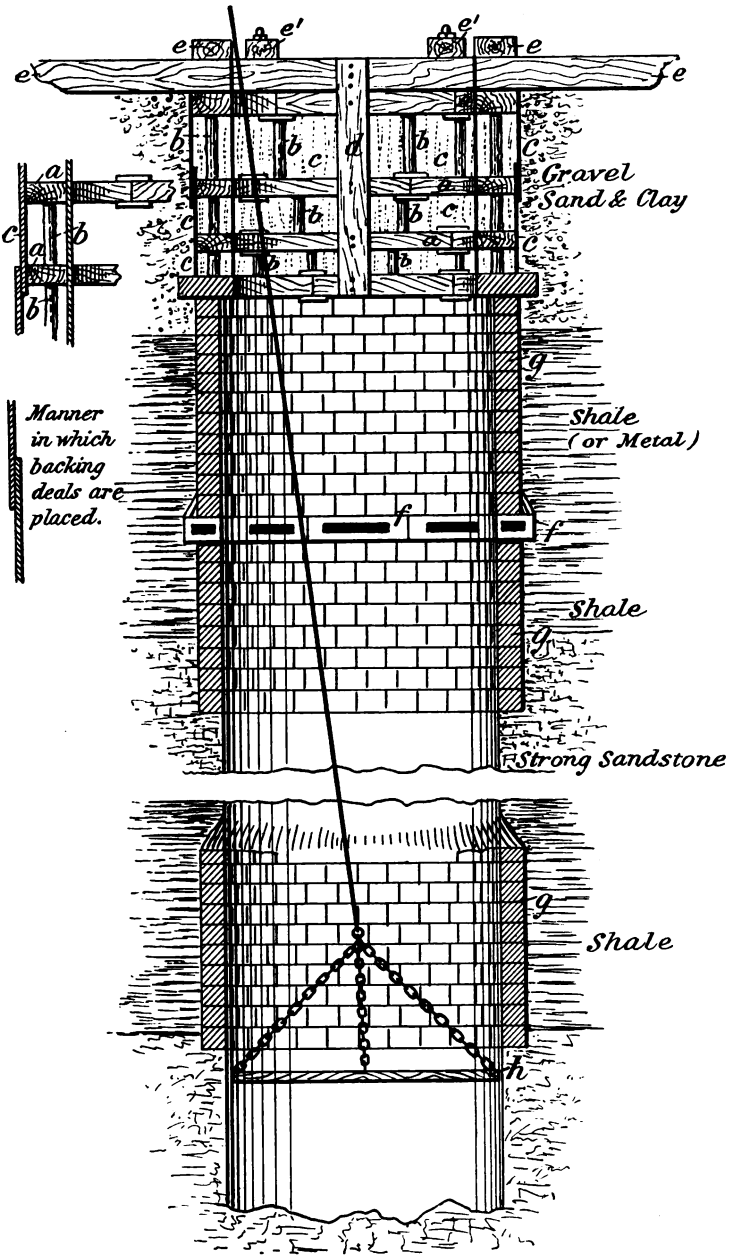


FIG. 73.—Section of a shallow Shaft of Small Diameter showing (*a*) Cribs; (*b*) Punch Props; (*c*) Backing Deals; (*d*) Stringing Deals; (*e*) Sills from which Stringing Deals are hung; (*e'*) Sills for Trolley Rails; (*f*) Walling Curb; (*g*) Walling; (*h*) Walling Platform.

of a shallow air shaft of small diameter which was sketched by the author some years ago. The hoisting arrangements adopted in this instance were those illustrated in Figs. 15, 16, and 17.

Walling.—The process of walling is as follows:—

A scaffold is erected about 12 feet from the ground, from which are hung lines forming a circle about 18 feet in diameter, which act as guides to the masons engaged in walling. The walling may be done, and often is, with ordinary bricks, but it will be better to construct it of fire-clay lumps accurately moulded to the radius of the pit. These will be set with lime, and as the temporary timber supports are carefully removed, the space between the walling and the side of the shaft will be firmly packed with clay or ashes or some other suitable material, which should be well rammed. If much water is being given off, it will be well to use cement instead of lime; or perhaps the method of walling known as "coffering," and described later on, might be resorted to.

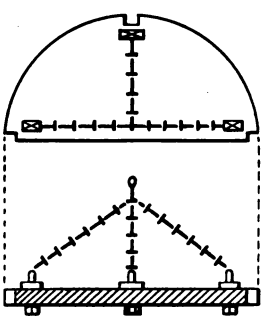


FIG. 74.—Walling Platform or "Cradle."

Walling Stage, Platform, or Cradle.—The walling stage or scaffold (Fig 74) is usually suspended from six chains made of best wrought-iron, $\frac{3}{4}$ inch diameter, there being three chains to each "half-moon." The chains, which are about 50 yards long, are hung from balks, 12 inches square, bricked into the shaft side, the bull stakes being shown in Fig. 75. As the sinking proceeds the chains are lowered and similarly fastened. The stage scaffold is made in two halves of planking about 3 inches thick, and when these

are fastened together the whole platform is about 6 inches less diameter than the shaft, so as to be less liable to catch the sides and disturb the lines suspended for walling. The eye-bolts, to which the chains are attached, are fixed in three points of the semicircle, the chains fastened to them being generally about 12 feet long, and joining together at the apex in one large link which may be attached to the winding rope or special rope for the purpose; and each half-moon may be raised or lowered independently of the other. Short chains, 2 feet 6 inches long, with a hook at each end, are required for suspending the half-moon to the scaffold chains hung round the shaft sides.

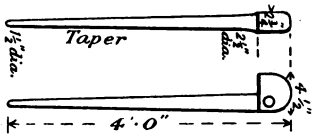


FIG. 75.—Bull Stakes.

Figs. 76, 77, show in detail the construction of a somewhat different scaffold, made of 3 inches timber with 4 inches cross pieces, and hinges of $\frac{3}{4} \times 1\frac{1}{2}$ inch iron. In the particular instance in which the latter platform was used, it was 4 inches less in diameter than that of the finished shaft. It consisted of three parts, a central one and two side pieces working on hinges; and was suspended in the shaft by ropes attached at the upper end to capstan drums, and so that it could be raised or lowered as desired.

Walker's Walling Scaffold.—Combined with Walker's sinking frame (see page 63) is a walling scaffold (see *d*, Fig. 50), by means of which bricking or tubbing can be carried on at the same time as sinking. When the first curb has been set, the circular scaffold is so lowered that it is slung immediately inside the curb, there being between the curb and the scaffold a stout rubber tube, which, being connected with the

compressed-air main, can be inflated, so as to make an absolutely water-tight joint, and all the dropping water can be caught and conveyed by the curb channel to the sump. In the centre of the scaffold is a circular opening (*e*) for

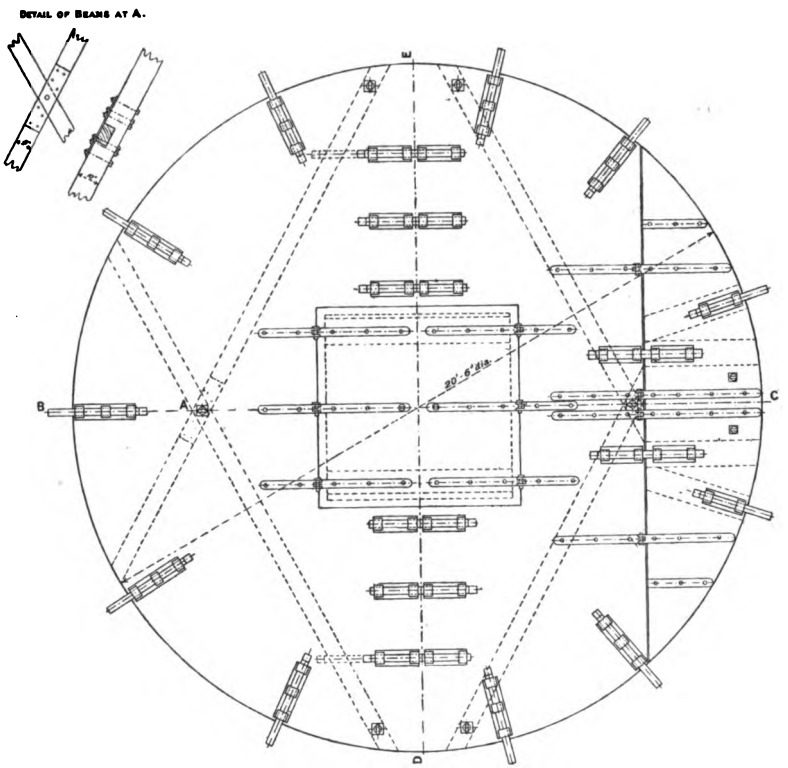


FIG. 76.—Plan of Walling Stage or Cradle, constructed of Wood, for a Pit 21 feet in diameter. (Messrs. J. Cook, Sons & Co., Ltd.)

the passage up and down of the sinking kibble (*f*), this opening being fitted with automatically closing doors. The guide ropes (*g*) of the scaffold also act as conductors for the kibble.

Maintenance of the Verticality of the Shaft.—For this purpose a centre cord will be used, made of hemp about $\frac{3}{8}$ inch in diameter, and of a length sufficient

to reach to the bottom of the shaft when finished. One end is wound round a small wooden drum fixed near the mouth of the shaft, the other end being passed over a small pulley and dropped through a hole bored in the middle of a balk of timber which is placed in the exact centre of the shaft. This cord carries at its extremity a small link to which a weight can be attached to steady it when the sinkers try the plumbness of the shaft. After "centreing" the shaft, the cord is

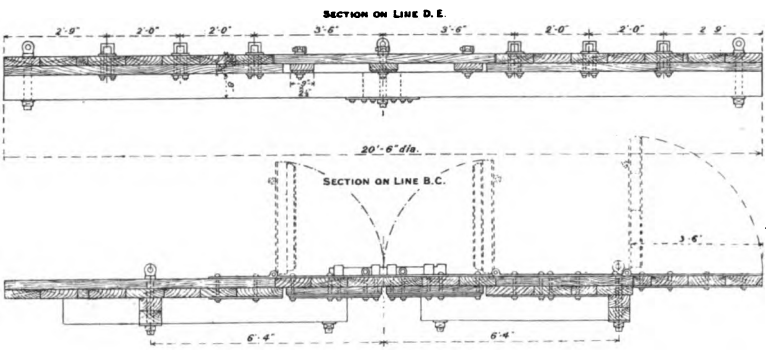


FIG. 77.—Section of Walling Stage. (Messrs. J. Cook, Sons & Co., Ltd.)

wound up until the link comes in contact with the balk. A centre staff is also used, which is usually $1\frac{1}{2}$ inch square, and, for an 18 feet diameter shaft, about 12 feet long. Two notches are cut in it, one at 9 feet from the end, marking the inside or net radius of the shaft, and one, say 9 feet 10 inches, allowing 10 inches for the brickwork, which is the measure of the outer or gross radius of the shaft. By using this staff the sinkers are enabled to determine whether a sufficient quantity of stone has been taken off the sides to allow of the walling being built.

Templates are used by the bricklayers to enable them to maintain the correct curve of walling. They are usually made of wood about $\frac{3}{4}$ inch in thickness and

4 feet long, the outer edge being curved to a radius of 9 feet (in the case supposed) and the inner planed straight and used as a "straight-edge." The side as well as the centre lines are made of ordinary cord, $\frac{1}{8}$ inch in diameter, and the former are used for setting out the walling from one curb to the other, and are generally placed 3 feet apart round the inside of the shaft (see Fig. 78).

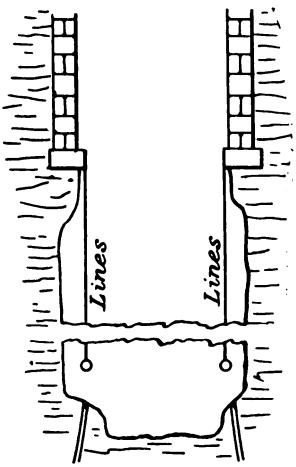


FIG. 78.—Manner of Suspending Side Lines.

Top of the Walling.—When the cylinder of masonry has been carried up the shaft and to some little height above the surface level, with a view to making a good solid foundation for the permanent heapstead, it will be well at this stage to erect from the clay foundation four sides of walling of 14-inch brickwork, enclosing a space of say 30 feet by 30 feet round the shaft, and fill the space between the circle and the square with concrete (Fig. 79).

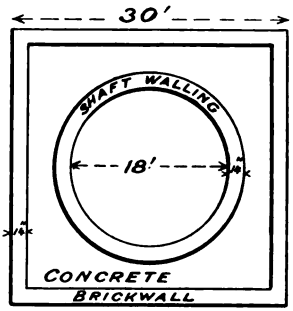


FIG. 79.—Surface Walling and Concrete.

Walling to Depth.—It may be supposed that the shaft has been sunk into the stone-head, a curb laid, and the first section of walling completed (Fig. 80), the headgear and engines installed, and all is in order for sinking to depth.

A simple metal walling curb has been illustrated in Fig. 81, but oak rings are sometimes used instead of metal, and sometimes hollow

metal curbs. The stone or brick used in the walling should be dressed or moulded, as the case may be, to true form to suit the radius of the pit. Under the wedging curb the pit is continued for 3 feet or more at the diameter of the finished pit, and then gradually enlarged to the full 18 feet. On reaching rock suitable for forming the bed of a walling curb, and it being deemed desirable to put in another course of walling, the seat is made and the curb laid in the manner already described. When the walling reaches the point at which it is necessary to remove the bracket left to support the curb above, great care has to be exercised in the gradual cutting away of the stone forming the same, and quickly advancing the walling and supporting the curb by punch props as the stone is removed; the walling being built up section by section, and only sufficient stone removed at one time to enable one section to be closed before commencing on another. The mortar used for walling is usually composed of lime and sand or ashes—and cement, as has been said, where the sides give off much water.

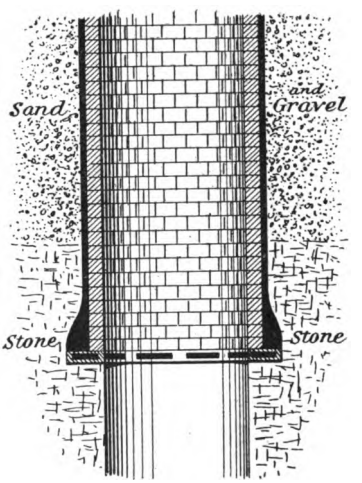


FIG. 80.—Shaft Walling.

FIG. 81.—Cast-iron Bricking Curb, eight segments to the circle.

Laying of a Wedging Curb and Erection of Tubbing.—On entering water-bearing strata, the feeders from which are too great to allow of the shaft

being encased with ordinary walling, either coffering or metal tubbing will have to be resorted to. The former, though practised elsewhere, is perhaps more in favour in the Midland mining districts than in other parts of the United Kingdom.

Metal Tubbing.—Where the method of tubbing is adopted (Fig. 81), sinking must be continued until the shaft has entered into a bed of firm rock in which a wedging curb can be laid, during which time the pumps will be constantly employed in draining out the water. The bed for the curb is first very carefully trimmed, being made perfectly horizontal, and covered over with thin fir sheathing, $\frac{1}{2}$ inch to $\frac{3}{4}$ inch thick, and tarred flannel. The segments of the curb are then laid on the same, and tarred flannel inserted between the joints of the segments, to ensure the curb being watertight.[1] When the circle has been completed the centreing is checked with the centre line, and the level with staff and spirit-level. Small pieces of oak are then put in behind the curb, and between these and the side of the shaft a packing of dry moss. Wedges are driven in between the pieces of wood; and, when it is impossible to drive in any more, holes are made by driving tubbing-chisels (see Fig. 83) into the wood and withdrawing them by means of a toothed draw

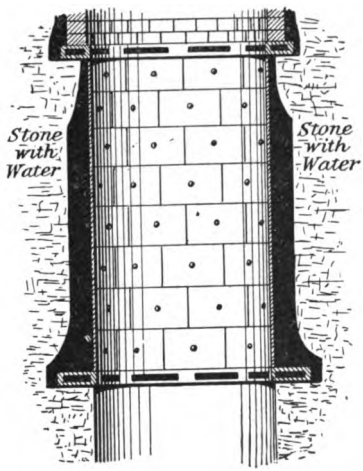


FIG. 82.—Metal Tubbing in a Shaft.

[1] Sometimes fir sheathing, $\frac{1}{4}$ inch to $\frac{3}{8}$ inch thick, is made to serve the same purpose.

bar, and oaken wedges inserted and driven home; this process being continued until it is found impossible to force in the chisel. Fig. 84 depicts a wedging curb in plan and section and three courses of tubbing, as made by Messrs. J. Cook, Sons & Co., Ltd. (County Durham), for an 11 feet diameter pit. Whilst the wedging is being carried out there will be a tendency for the curb to rise, to prevent which, punch props must be set in the manner shown in Fig. 85. The hollows in the curb are filled with pieces of oak to keep out moisture. Such a curb would be (cast-iron) 6 to 8 inches deep, 13 to 18 inches broad, and usually about $1\frac{1}{4}$ inch thick, but the dimensions will be determined according to the pressure it has to support and the diameter of the pit. Sometimes, in order to ensure a perfectly level bed for the metal curb, a wooden one is laid first as a foundation for it, and, occasionally, iron curbs are laid one above another to secure the same end. Too much care cannot be exercised in the laying and fixing of a wedging curb, as it has to constitute a water-tight base for what may be a considerable height of tubbing.

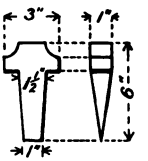
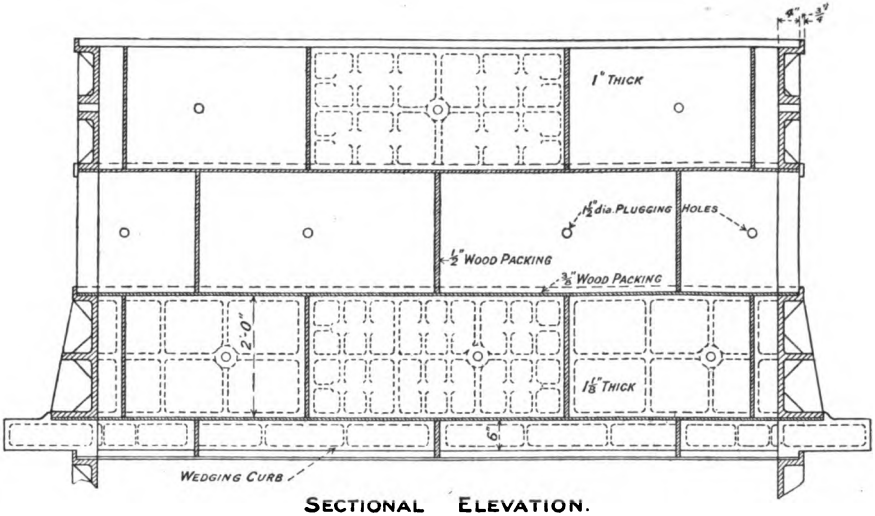


FIG. 83.—Tubbing Chisels.

Cast-iron Tubbing.—Preparatory to building up the tubbing, the surface of the curb is covered with fir sheathing and tarred flannel to the thickness of about 1 inch. The segments of tubbing, which are of iron, are carefully cast to the radius of the pit, and of such thickness as is necessary to effectively resist the pressure in any given instance (see page 108). They are usually 2 feet deep by $4\frac{1}{2}$ feet long, and strengthened in the manner shown in Fig. 86, having a hole in the middle to allow of the efflux of the water when being set, and of easier handling when about



SECTIONAL ELEVATION.

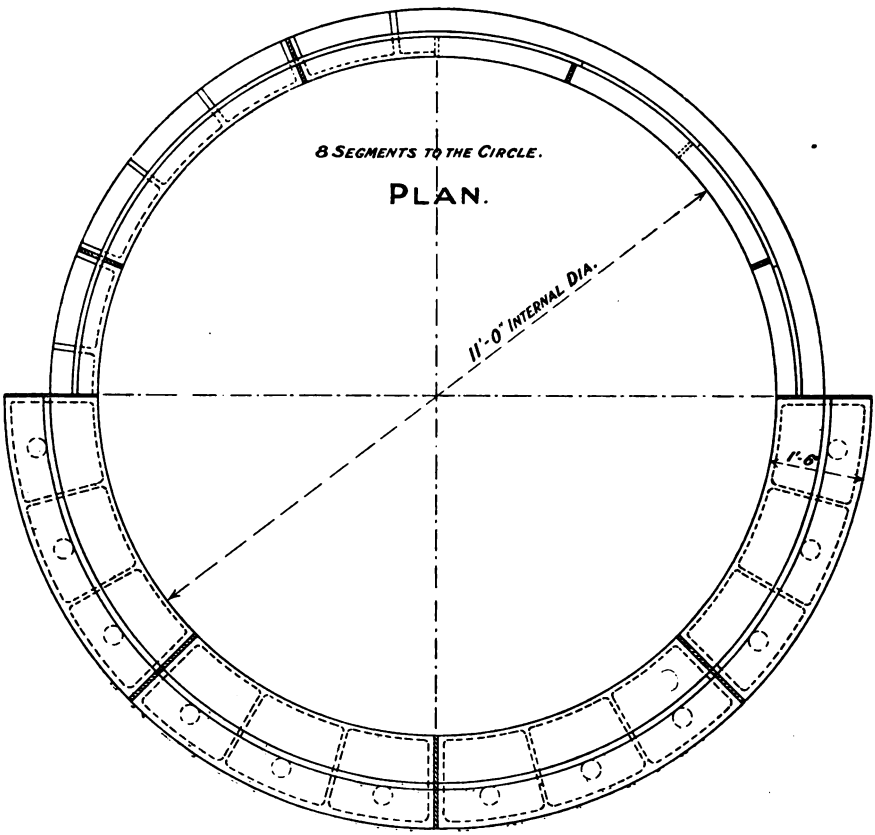


FIG. 84.—Plan and Sectional Elevation of a Wedging Curb and Cast-iron Tubbing. (Messrs. J. Cook, Sons & Co., Ltd.)

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to be lowered into the shaft. The segments are built upon the curb one above the other, care being taken to have the joints "off and on," after the manner of a brick or stone wall. Fir sheathing $\frac{3}{8}$ inch to $\frac{1}{2}$ inch in thickness is placed horizontally and vertically between each segment, and the vertical joints tightly wedged with oak or pitch pine wedges until it is impossible to force in any more, tubbing chisels being used to make the aperture for the insertion of the additional wedges between those first put in; but the wedging of the horizontal joints is left until a sufficient height of segments has been erected, or the column has been surmounted by another wedging curb, or has reached the stone walling above, so that lifting of the tubbing by the wedging is rendered impossible. Then, beginning at the bottom, oaken plugs are driven into the centre holes as the water rises behind the plates, and the wedging of the joints is completed. Sometimes it is deemed well to leave the wedging of the vertical joints, as well as of the horizontal joints, until the closing of the cylinder of tubbing. Every segment, before being put in, should be well tested by punching it at all its edges, in order to be certain that the metal is sound and free from honeycombing, often caused in the casting. Care must be taken to allow of the free escape above the water of the air and gases behind the tubbing. In some cases, owing to the very heavy feeders of water, but little depth can be

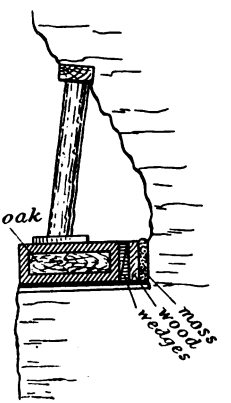


FIG. 85.—Cross Section of Wedging Curb.

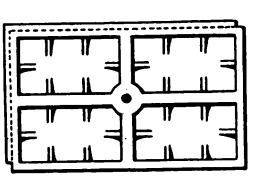


FIG. 86.—Segment of Cast-iron Tubbing.

attained before it is necessary to lay a curb and put in a section of tubbing to keep back the water. Mr. Emerson Bainbridge[1] mentions a case where no less than thirteen curbs had to be laid within a distance of 250 feet on this account—that is to say, a curb was placed wherever a bed of stone appeared to form a natural barrier between two distinct feeders of water, so as to render pumping less necessary, the cost of laying so many curbs being, of course, very heavy. In such cases the fact of allowing for the exit of air and gases is sometimes overlooked. Pass-pipes (1, Fig. 87) may be placed from the top of one course to the bottom of the next above. A better method, however, is to have the wedging curbs made with a hole say 3 inches in diameter, and an accurately fitting valve placed therein (2, Fig. 87), the effect of which is to give relief to the accumulated gases below and yet prevent the passage of the water from the upper to the lower "lifts" of tubbing.[2] This arrangement presents a further advantage, in that should at any time tubbing be broken, or the wedging give way, whilst repairing operations

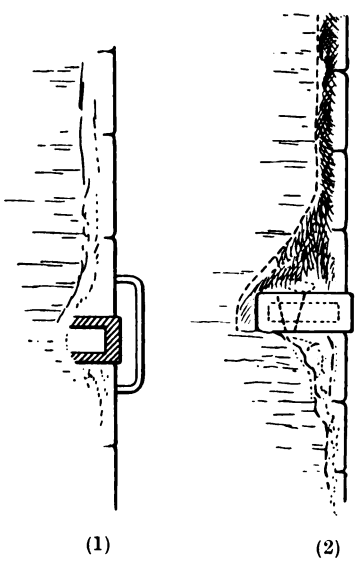


FIG. 87.—(1) Pass-pipe to allow of passage of Gas behind Tubbing; (2) Valve to allow of passage of Gas behind Tubbing.

[1] *Transactions Inst. C.E.*, vol. xxxiv.

[2] The latter an eventuality of common occurrence in upcast shafts where the ventilation is produced by furnace, or where there are underground boilers, the expansion and contraction due to variation of temperature in the shaft often causing serious leakages.

are being carried out, the only feeders of water that have to be contended with are those behind the particular lift or section of tubbing which is damaged. Sometimes when the pressure becomes excessive the water is conveyed down the shaft to the standage and pumped to the surface, but there is no necessity for doing this if the tubbing is of sufficient strength and has been properly put in. The neglect to provide an outlet for the accumulating gases which may exist in the strata through which tubbing has been carried has sometimes led to the latter being seriously damaged or displaced a short time after being fixed. The pass-pipes or valves mentioned above obviate this and give the necessary relief through each wedging curb. But these means may prove ineffective if no provision is made for the emission of the gases at the extreme top of tubbing; hence it is sometimes left "open-topped," that is, is built up a few feet above the water-level, instead of being closed underneath the curb above; but where it is close-topped, *i.e.* built up against a curb, the plug-holes should be left open in say the two top courses, and care taken that they do not get closed; or the holes in all the tubbing but one may be closed, and into the unclosed hole a pipe fitted either to convey the water to the level of the standage or to a sufficient distance up the shaft.

Fig. 88 shows an arrangement adopted at the sinking of the Canklon pit in Yorkshire,[1] where the wedging curbs were put in at about every 25 yards, and were 18 inches wide, the beds being prepared with the greatest care, a space of only 2 inches being left behind the curb, which was filled with blocks of Russian pine and then wedged, the wedging of a curb occupying four

[1] "Canklon and Denaby Main Caderby Sinking," by E. F. Melly, *Trans. Brit. Soc. M.S.*, vol. xiv. p. 53.

continuous days. The first ring of tubbing was made, as shown in the figure, with an especially large foot in order to afford a better support to the higher segments. The air behind the tubbing was liberated through the medium of a 2-inch diameter pipe, which was carried right through the curb behind the tubbing and up to the next curb. When the tubbing was wedged and plugged and the water rose, the air escaped downwards through the curb. After the water had run for some hours through the pipe and the whole of the air was expelled, the valve V was shut.

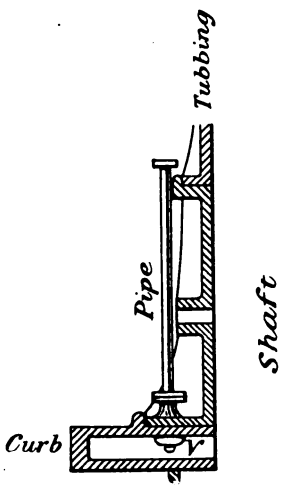


FIG. 88.—Wedging Curb as used at the Canklon Pits, Yorkshire.

This tubbing, which varied between $\frac{3}{4}$ to $1\frac{1}{4}$ inch thick, cost about £5, 10s. per ton delivered. It contained brackets cast on every third ring for future installation of pipes or girders.

Metal Tubbing in Furnace Shafts.—Although ventilation by furnace is largely giving place to ventilation by mechanical means, furnaces are still used as the means of inducing the air current in many well-ventilated collieries. Where such is the case, and where metal tubbing is put in in the upcast shaft, it should be protected from the action of the sulphurous vapours generated in the burning of the coal. This can be done either by having wedging curbs cast $4\frac{1}{2}$ inches deeper in the bed, and projecting into the pit to that extent, erecting a brick lining thereon and carrying it up to the next curb, or by having the tubbing segments cast with "inside brackets"—that is, the strengthening brackets facing

inwards to the centre of the pit instead of being behind the tubbing; and filling the spaces between the brackets with a firebrick lining. The latter is the most advantageous method to pursue, as the joints are more easily got at for wedging should any leakage occur through contraction of the tubbing owing to variations of temperature. The joints can be protected by the insertion of a small loose brick.

Resetting Metal Tubbing in a Shaft.—Fig. 89 illustrates the manner of "fore-setting" a shaft, the tubbing of which had given way owing to the action of the furnace gases on the metal. On the sides showing signs of collapsing, timbering was commenced from bank (surface) and carried down to the top of the tubbing, backing deals being used, supported by oak curbs set 3 feet apart. The lower lengths of old tubbing which showed greatest signs of collapse were stripped and wedged and walling carried

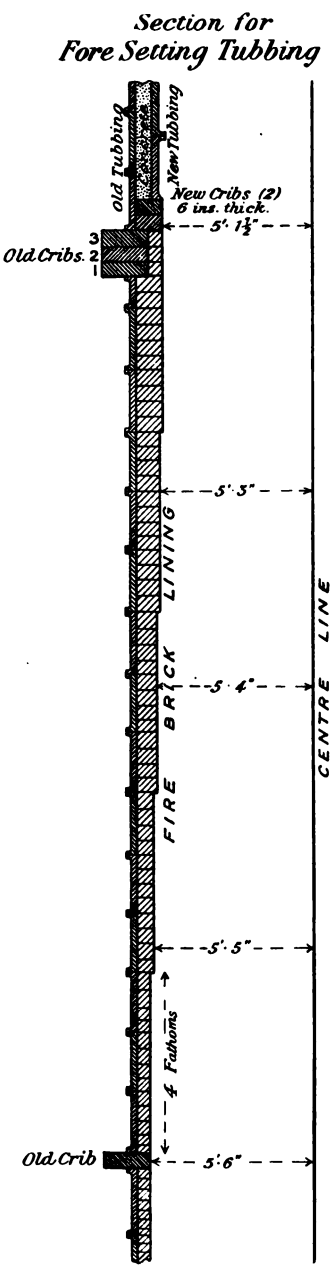


FIG. 89.—Section showing a Method adopted for Resetting Tubbing in a Shaft.

up in front of the same in the manner shown, and a foundation made for two new wedging curbs. A bottom course of tubbing, the segments having a double flange, was then put in and cemented for a distance of 2 feet up the shaft, after which 4½ inches brickwork was built between the flanges in the manner already described, and concrete poured in between the old and new courses of tubbing.

Size and Strength of Walling Lumps and Tubbing Segments.—The walling of shafts is built of ordinary bricks 9 inches by 4½ inches by 3 inches, fireclay lumps 24 inches by 9 inches by 6 inches, stone, or concrete, but the latter is seldom used by itself—though there seems no reason why ferro-concrete would not constitute an effective lining material (and an instance of its application to this purpose is quoted on page 117). The thickness in inches that walling should be, may be calculated by the following formula—

K = the thickness of the walling in inches.
r = the external radius of the proposed cylinder of walling.
T = the ultimate crushing strain in pounds per square inch.
p = the head of water in lbs. per square inch.

Then for a cylindrical dam or shaft walling—

$$K = r\left(1 - \sqrt{1 - \frac{20}{T}}\right)p$$

10 being taken as the factor of safety and allowed for in the formula. The average value of T in the case of some materials which might be used for lining shafts may be taken as follows :[1]—

Wrought-iron	T = 38,080
Cast-iron	,, = 107,520
Brickwork in cement	,, = 51,520
Oak (English)	,, = 10,000
Pitch pine	,, = 8,000
Brick (common)[1]	,, = 2,822

[1] Staffordshire blue brick has a crushing strength of from 2·68 to 3·27 tons per square inch.

Brick (Stourbridge fire)	T =	2,038
Sandstone	,, =	2,464 to 12,096
Concrete (ordinary)	,, =	851
,, (in cement)	,, =	1,411

The determination of the proper thickness of metal tubbing is not such a simple matter as in the case of walling. If the formula just given be used for this purpose, and the value of T be taken at 107,520, the thickness of the tubbing for a depth of 300 feet and a diameter of shaft of 12 feet would be 1·44 inches. If the segments were always perfectly cast and of simple pattern —that is, made without ribs and stays—the problem of thickness would be an easier one. Any formula, in order to be trustworthy, must be conditioned by the design of the tubbing segment used, and must be the result of actual experiment. One formula will not suffice for the determination of the thickness of all types of metal tubbing.

The late Mr. G. C. Greenwell's well-known formula,

$$T = \frac{P \times D}{50{,}000} + 0{\cdot}03$$

in which T was the thickness of the tubbing in fractions of a foot, P the pressure in pounds per square inch, and D the diameter in feet, was evidently founded on, and is effective only for, the type of tubbing in use at the time at which he wrote his fine treatise;[1] and so far as the present writer is aware, no single case of rupture can be directly or solely attributable to insufficient thickness of tubbing put in in those days—that is, tubbing of the pattern for and on which the formula was founded, though corrosion of the cast-iron has in several instances necessitated its renewal.

The opinion of such an experienced engineer and sinking contractor as Mr. Coulson on metal tubbing is

[1] *A Practical Treatise on Mine Engineering*, by G. C. Greenwell, second edition, 1869, p. 171.

valuable. He has stated,[1] speaking from a knowledge extending over a period of thirty-five to forty years, that he did not know of any tubbing in the north of England being made without a specification giving the mixture of metal, method of making and cooling it, and the best means for testing it. If such a specification were prepared and carried out, he did not think there was any need for an allowance for faulty casting. "It was suggested that the old method of tubbing with sheeting and wedges was obsolete, and that the proper method was to use bolted tubbing packed with cement. So far as it went, that was right, but there were certain conditions when bolted tubbing would be an utter failure, and he did not know of any case where tubbing packed with cement . . . had been absolutely successful in keeping the pressure off the tubbing itself. It was, however, sometimes successful when allowing the water to pass up or down, but it was quite possible to meet with a pressure of water from a lower feeder very much in excess of the pressure due to the level of the water in the pit, and several accidents had occurred from that cause. Sometimes if a lower feeder, coming from a much higher source, could not pass freely behind the tubbing and escape at the water-level in the shaft, it exerted much greater pressure than was expected. He had visited a place in Germany not long ago where bolted tubbing was put in, and the whole of the bottom length was blown out from the cause stated. It seemed to be taken for granted that cast-iron tubbing 2 inches thick would be twice as strong as cast-iron tubbing 1 inch thick, but this did not work out in practice. Flanges were, of course, an important factor in tubbing." He regarded flanges as very important factors in securing the strength of the

[1] Discussion by Mr. Coulson on Mr. H. W. G. Halbaum's paper on "Cast-iron Tubbing: What is its Rational Formula?" *Trans. Inst. M.E.*, vol. xxxv. p. 48.

segments; so important had they been considered, "that it had been the practice for many years to reduce the depths of the segments from 2 feet to 18 inches in order to get more flanges into the circle below a certain depth."

Mr. Isaac Hodges, when calculating the thickness of tubbing for lining the shaft at Methley Junction Colliery,[1] near Leeds (Yorkshire), investigated the formulæ advanced by various experts for this purpose, and was struck by their disparity, and the small margin allowed for corrosion and general deterioration. Experience with earlier tubbing at the colliery had shown that the latter constituted a considerable factor in the case and should be allowed for—deterioration both in thickness by active corrosion—internal and external—and deterioration of the quality of the metal; and he gives the following Table showing the comparative thickness for given depths as determined by the formulæ of various authorities :—

TABLE VII.—*Thicknesses of Metal Tubbing according to various Authorities.*

Height of Tubbing.	Name of Expert.				Tubbing in Methley Junction Shaft.
	J. J. Atkinson.	W. Galloway.	G.C.Greenwell.	W. Tate.	
Feet.	Inches.	Inches.	Inches.	Inches.	Inches.
	1. Shaft: 10 feet in diameter.				
60	0·22	0·05	0·50	0·23	0·75
100	0 30	0·09	0·60	0·39	0·87
140	0·37	0·13	0·69	0·54	1·00
180	0·44	0·17	0·79	0·70	1·12
220	0·51	0·21	0·88	0·85	1·25
260	0·58	0·25	0·98	1·00	1·37
	2. Shaft: 11 feet in diameter.				
300	0·70	0·32	1·15	1·27	1·50
340	0·80	0·36	1·26	1·45	1·62
380	0·90	0·41	1·36	1·62	1·75
420	1·00	0·45	1·46	1·79	1·87

[1] "An Account of Sinking and Tubbing at Methley Junction Colliery, &c.," by Isaac Hodges, *Trans. Inst. M.E.*, vol. xxxii. p. 96.

It will be observed that the thicknesses he decided upon exceeded those determined by all of the formulæ. The type of segment adopted for tubbing the shafts was similar to that in use at the time when Greenwell framed his formula.

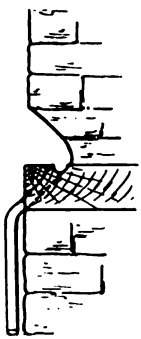


FIG. 90.—Oaken Water-Ring.

In arriving at the value of "P," it must be borne in mind that the head of water at any one point is not necessarily that due to the vertical depth from the surface to the point in the shaft in question, but, in the case of water-bearing strata lying between impervious beds, the height of the outcrop of such bed above the point in the shaft where the tubbing is to be put, which may be greater, and necessitates careful levelling for its determination before the value of this factor in the calculation can be arrived at.

Water-Rings.—Rings, termed variously water-rings, water-curbs, or water-garlands, for catching such water as runs down the sides of the finished shaft, are inserted during the process of walling or tubbing the shaft, to prevent the water interfering with the walling of a lower section of the shaft, or for the purposes of holding and supplying pure water below ground, two different types of which are indicated in Figs. 90 and 91. The water caught in these rings is conveyed underground in pipes, and being frequently of good quality, is used in the stables, or for other purposes. Water-rings should be laid on solid ground

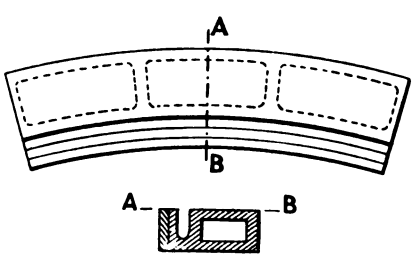


FIG. 91.—Cast-iron Wedging Curb and Water-Ring combined.

or substantially built brickwork, on account of the penetrating influence of the water.

A good method of laying a water-ring when walling is, after fixing the walling curb, to brick up for a few yards, using cement instead of lime, and to puddle well the space between the bricking and the shaft side, or filling it with concrete and laying the water-ring on this foundation; but the best way is to make the walling or tubbing curb itself the water-ring, and have it cast with a channelled ring for the purpose (Fig. 91).

CHAPTER V

LINING OF SHAFTS (*continued*): SOME FURTHER METHODS

Plank Tubbing.—Plank tubbing, which consists in holding together bevelled planks by means of rings similar to the method adopted in barrels (see Fig. 92), has sometimes been used for lining shafts; a notable instance is that of Hebburn Colliery, sunk about the year 1790—when the method pursued was as follows:[1]—

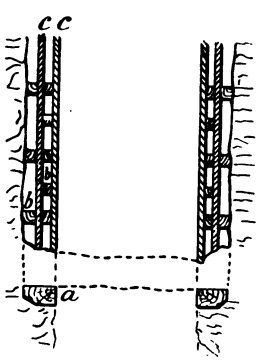


FIG. 92.—Plank Tubbing.

A seat on which two foundation wedging curbs were to be placed was carefully levelled and its surface covered with flannel (or white lead, or some other yielding substance). On these the first wedging curbs (Fig. 92, *a*), consisting of oaken segments 8 or 9 inches square, were laid, then deals (sheathing) were placed between the joints, and wedged. At intervals of 18 to 30 inches, according to the pressure expected, ordinary spiking curbs (*b*) were placed and wedged tight to hold them in place, after which well-planed planks, $2\frac{1}{2}$ to 3 inches thick, in 8 to 10 feet lengths, with joints bevelled to the circle of the shaft, were fastened to the curbs by spikes; these were at first of iron, but,

[1] *A Treatise on the Winning and Working of Collieries*, by Mathias Dunn, second edition, 1852, p. 47.

owing to the deteriorating action of the corrosive water, copper spikes were afterwards substituted.

When well executed, it is said that this type of tubbing will withstand a pressure of 100 lbs. per square inch, and endure for many years. But the disadvantage of the system lies in the eating away of the spikes and consequent leakages, which fault led to the adoption, at some places, of *solid wood or curb tubbing*, which possessed the advantages of not requiring either planking or spikes. In the latter system it is necessary to carefully pack the space between the tubbing and the shaft with ashes or some such material, and the tubbing itself must be tightly wedged. Fig. 93 illustrates another, and somewhat similar, mode of carrying out solid wood tubbing. It will be seen that the blocks of wood in this case are not curved.

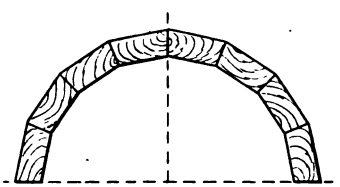


FIG. 93.—Solid Wood Tubbing.

Coffering of Shafts.—Where the strata sunk through give off much water, a system of brickwork termed "coffering" is sometimes resorted to in preference to metal tubbing. In some parts of the Midlands this mode of lining "wet" shafts is in particular favour, though in the north of England tubbing with cast-iron segments is preferred.

When about to adopt the coffering process, it is advisable to sink well below the water-bearing strata—several feet at least—in order to construct a good foundation for the coffering, and having obtained a strong rock on which to commence operations, solid brickwork, say 2 feet thick (see Fig. 94), is put in and carried up to the level of the lowest feeder of water, at which point the "plug" boxes, usually numbering about four, are placed

round the shaft at equal distances to act as drains for the water; these are made of oak, usually 12 inches square and 2 feet or more long, and set with cement; through each a lateral hole being bored, about 3 inches in diameter, meeting a vertical hole in which is placed the perforated water trough, also of wood, having holes every few inches apart on opposite sides; the holes being plugged as the walling mounts up, and when it is completed the plug holes in the boxes are also wedged and the water troughs filled with cement. When sinking below the feeders of water in order to secure a foundation for the coffering, it is well to go down several feet lower than at first sight appears requisite for this purpose, and well below the actual foundation, in order that, on the resumption of sinking operations, the brick base may not be shaken by the blasting. Care should be taken also to cross the joints of the brickwork both vertically and horizontally. The puddling is done with either clay or soil well screened and rammed—soil was used in preference to clay at a recent sinking in South Staffordshire.

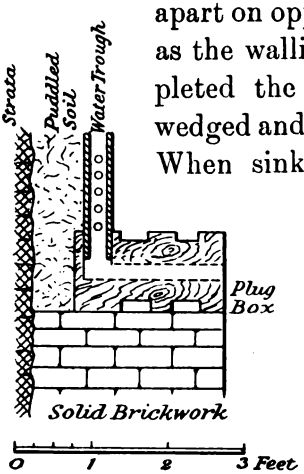


FIG. 94.—An Arrangement of Plug Boxes and Water Troughs in Coffering.

In the sinking of the Newdigate Colliery shafts in Warwickshire[1] a considerable quantity of water (10,000 gallons per hour) was met with in each shaft in the first 50 yards of the sinkings, which was pumped out by two 8-inch pumps and afterwards stopped back by coffering. The coffering curb was 2 feet 9 inches on the bed, and was wedged up in the same manner as a wedging curb for iron

[1] "Newdigate Colliery," by C. E. J. M'Murtrie, *Trans. Brit. Soc. M.S.*, vol. xxiii. p. 43.

tubbing. On this was built, for a height of 5 yards, solid cemented brickwork 3 feet thick, on which were laid ten cast-iron plug boxes. The depth to the bottom of the coffering curb was 60 yards.

Thickness of Coffering and Tubbing.—Professor Galloway gives the following formula for calculating the thickness of coffering and tubbing to resist the pressure of water in a circular shaft :—

T = thickness in inches of the material to be used.
D = internal diameter of the shaft in inches.
H = the head of water in inches.
W = the weight of a cubic inch of water = $\frac{62{\cdot}5}{1728}$ lbs.
R = 33 per cent. of the co-efficient of resistance to crushing per square inch of the substance to be employed in the coffering or tubbing.

$$\text{Then } T = \frac{WHD}{2(R + WH)}.$$

Taking a 20 feet diameter pit and a head of 450 feet, this gives for brick 44 inches and cast-iron 1·72 inches.

Use of Reinforced Concrete in Lining Shafts.—At Béthune Colliery in the Pas-de-Calais, reinforced concrete was recently used as a shaft lining. Rings of steel plate 40 mm. by 10 mm., and of a diameter 8 cm. greater than that of the shaft, were fixed in the shaft and spaced according to the strength of the sides, and connected to each other by four series of vertical ties in steel plate of the same cross section as that of the rings. Concrete was then deposited in sections of 4 m. high behind moulds formed of boards with grooved joints and braced so as to resist the pressure of the concrete. The cost of this lining was said to be 35 per cent. less than the masonry lining previously adopted at these collieries.

The Simultaneous Sinking and Lining of

Shafts.—The lining of shafts has been safely carried out simultaneously with the sinking on several occasions when rapidity of execution was deemed more than usually pressing, but there exists among mining engineers a natural antipathy to the procedure in the interests of safety.

At a Belgian Colliery.—In 1893, in the Patience et Beaujonc concession at Glain-Lez-Liége, the sinking and lining simultaneously of a shaft, the diameter of which was 13 feet 11 inches, was commenced and safely carried out. In this operation use was made of a double platform, which served also as a template for the brickwork. This instance is remarkable also on account of the low cost of the work; the whole cost of the shaft complete not exceeding £7 per foot sunk.[1]

At Newbattle Colliery. — An interesting account, too, of walling and sinking simultaneously with Galloway's scaffold has been given by Mr. John Morison of a shaft which he sunk 20 feet in diameter to a depth of 1650 feet,[2] the arrangements adopted being illustrated in section in Fig. 95. Mr. Morison designed and used a cradle consisting of a protecting roof to a working floor, between which there was ample height for the men to work. In the centre of the cradle there was an opening to allow of the passage of two kibbles, the opening being fenced with $\frac{1}{4}$-inch sheet iron $6\frac{1}{2}$ feet high. The flooring was constructed of mild steel angle-bars 4 inches by 4 inches by $\frac{1}{2}$ inch, turned to the circle, covered by 5-inch planking; a door hinged to the floor was raised or lowered by block and tackle fastened

[1] "Creusement et Muraillement Simultanés du Nouveau Siége Fanny des Charbonnages de Patience et Beaujonc à Glain-Lez-Liége," by Léon Thiriart, *Annuaire de l'Association des Ingénieurs de Liége*, 1895, vol. viii. p. 236.

[2] "Walling and Sinking Simultaneously with the Galloway Scaffold," by John Morison, *Trans. Inst. M.E.*, vol. viii. pp. 118–122.

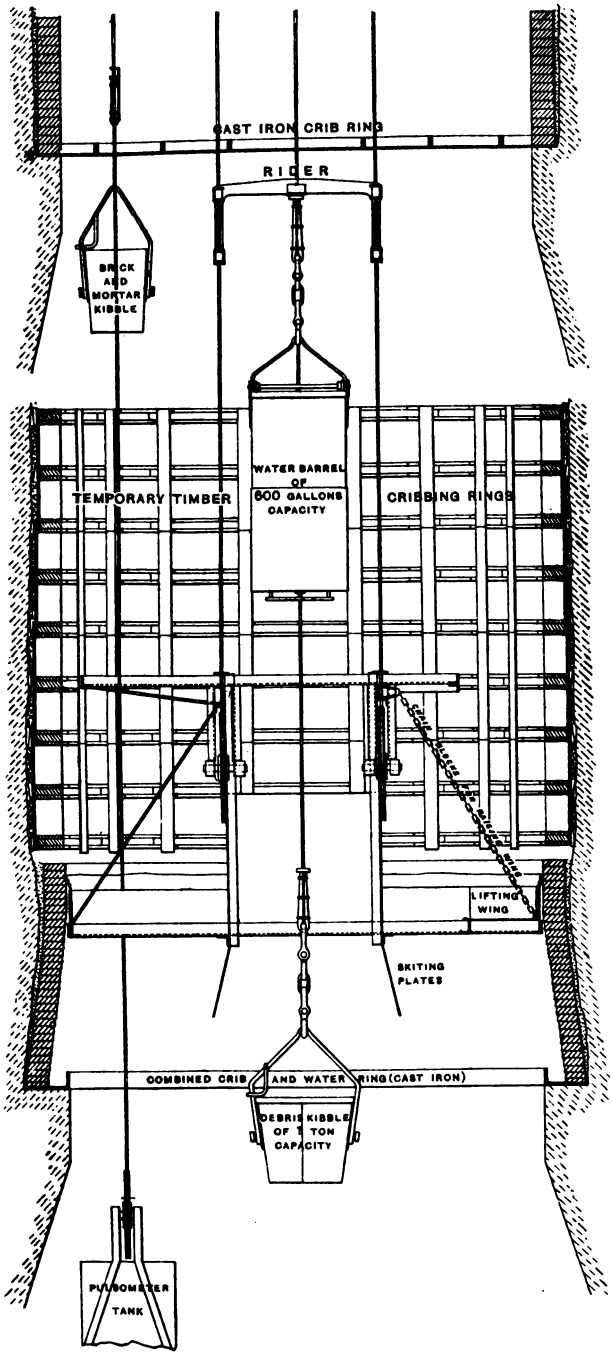


FIG. 95.—Arrangement used at Newbattle Colliery for Walling a Shaft whilst in course of being sunk.

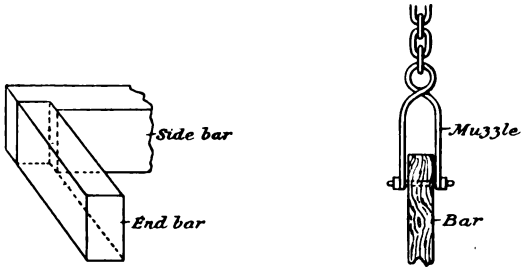
by shackles to the door and the framing of the scaffold; the door was recessed to permit of its closing on the air-box and pipes. The roof was constructed of angle-bars 5 inches by 5 inches by $\frac{5}{8}$ inch steel, covered with $\frac{3}{8}$-inch sheet iron plating, and four stays placed to four upright corner angle bars supported and stiffened the roof framing. For the purpose of strengthening and carrying the floor, two $1\frac{1}{2}$-inch tension rods were secured to the double angle-bars and to the outer ring of the floor. A fence of $\frac{3}{16}$-inch sheet iron, 18 inches high, was bolted to a circular framing round the scaffold, which was $1\frac{1}{2}$ inch less diameter than the shaft. Fending plates attached to the under side of the floor guided the swinging kibble through the opening. The weight of the scaffold was $8\frac{1}{2}$ tons, and when at work with men and material the total weight was about 20 tons.

Walker's Shaft-Sinking Frame. — It will be seen from Fig. 50 that Walker's patent shaft-sinking frame and scaffold combined, of which mention has already been made on p. 63, can be put to very similar use. The scaffold portion of this arrangement has not been yet alluded to. When the spot for laying the first curb has been selected, the scaffold is lowered and suspended immediately inside the same. Between the curb and the periphery of the scaffold a stout rubber tube is provided, which, being connected with the air-main, can be inflated and made an absolutely water-tight joint. The circular aperture which allows of the passage of the kibble is fitted with automatically closing doors, so that when the kibble has passed through, the bricklayers are provided with a complete floor to work upon and roof to protect them from water, &c. The kibble runs on guide ropes suspended as shown in the drawing.

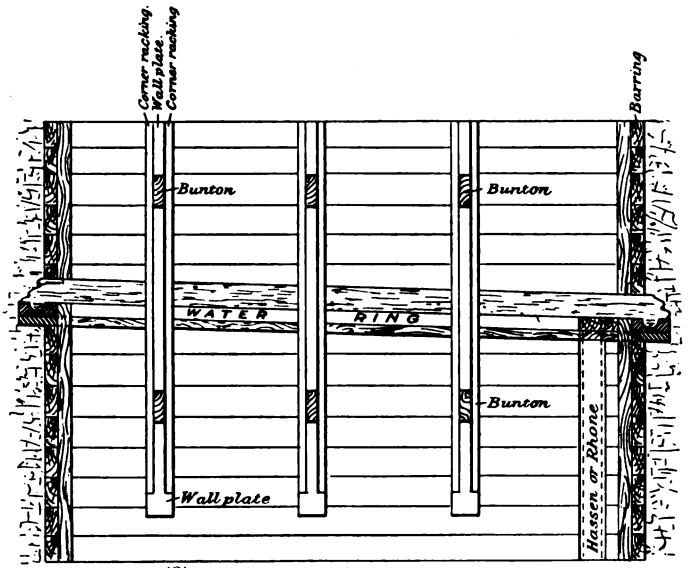
The Maintenance of Rectangular Shafts.—The shaft having been sunk to, and some distance into, the stone-head, it will become necessary to secure the sides, which is usually done with timber—pitch pine being most in favour for the purpose—the dimensions of the bars depending on the size of the shaft and strata sunk through. The bars having been cut into the proper lengths, and the "side" bars "checked" on one side at each end, so as to constitute a joint with the "end bars" (Fig. 96 (1)), they are lowered into the shaft in pairs by means of a muzzle (Fig. 96 (2)) which is attached to the winding rope through the medium of a chain.

When the sides of the shaft are not self-containing, complete timbering may become necessary, the distance apart of the timbers depending entirely upon the nature of the strata.

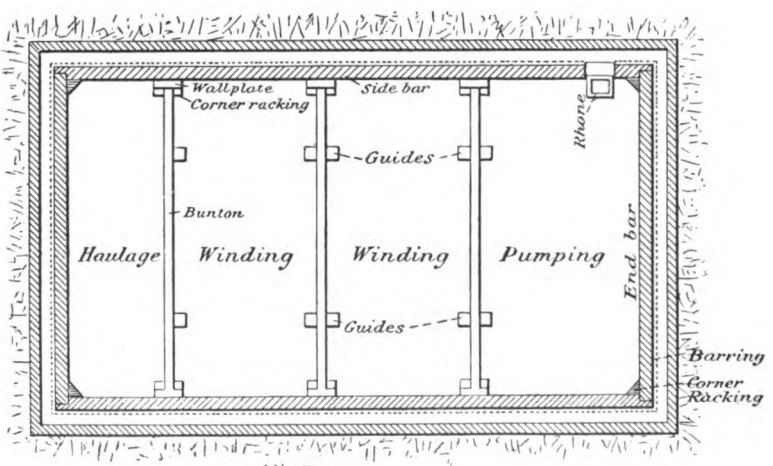
The first set of bars are set on a carefully dressed bed, tested with the spirit-level, and fixed at right angles by means of a set-square; wooden wedges being driven between the barring and the sides of the shaft. If the ground is bad and the timber has to be close-set, each succeeding set of bars is fitted close on to and flush with the lower set, and the space between barring and shaft sides filled with débris well packed; the workmen being guided in their work by means of plumb bobs suspended in each corner. In carrying out this work, at about every 6 feet a scaffold is constructed by the sinkers placing props across the shaft, fixed to the last set of bars, being made secure by brackets nailed to the barring; on these, planks are laid, and a second stage of barring built up, and so on until a sufficient height is constructed to necessitate the fixing of the "corner rackings" or running timbers, which are nailed to the barring at the corners of the shaft.



(1) (2)



(3) SECTIONAL ELEVATION.



(4) PLAN

FIG. 96.—Timber Lining of a Rectangular Shaft. (1) Joint of End and Side Bar; (2) Muzzle for lowering the "Bars"; (3) Vertical Section of Shaft showing Water-ring, &c.; (4) Plan of Shaft.

The scaffolding props (or "needles," as they are termed in Scotland), which act as a temporary support to the shaft, are not removed, but are utilised for the purpose of putting in the "wall-plates" and "buntons" after the barring has reached to the surface, the insertion of the wall-plates and buntons being carried down from the surface before the resumption of the sinking.

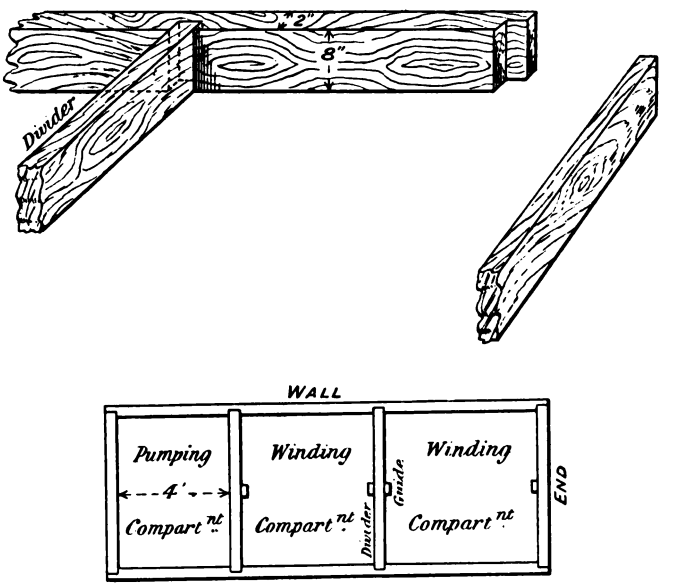


FIG. 97.—Timber Lining of a Rectangular Shaft.

The wall-plates are placed vertically and nailed to the side-barring and buntons, the latter being usually at distances 6 feet apart placed horizontally across the shaft and nailed to the wall-plates; corner rackings are nailed to the wall-plates on either side of the buntons to keep them secure (see Figs. 96 and 97).

On the completion of the first section of timbering as above, the sinking of the shaft is resumed and continued as long as is considered safe, then the sides

of the further section will be similarly supported. On completion of the shaft the guides or conductors will be put in, being carried up from the bottom in 20 or 30 feet lengths and fixed to the buntons, care being taken to have all screw bolts well counter sunk.

Various forms of joints or mortices are adopted in shaft-timbering, some of which are illustrated in Fig.

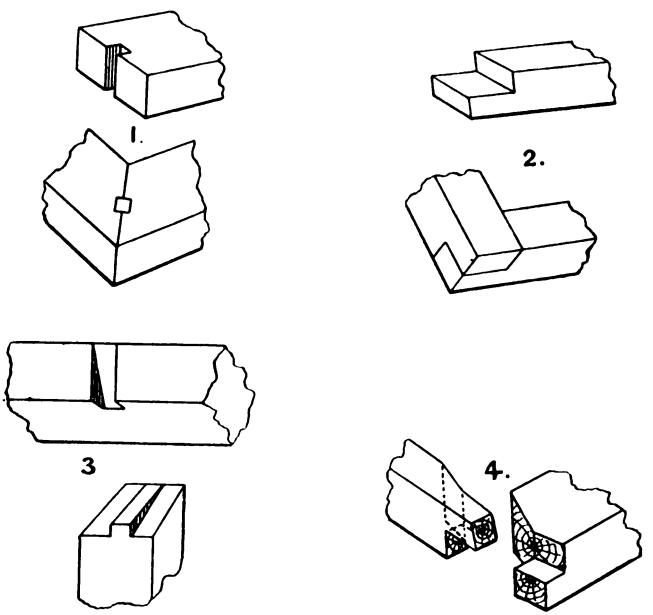


FIG. 98.—Various Forms of Joints for Shaft Timbers.

98. It should be borne in mind, however, that it is unwise to impair the strength of the timber by the removal of too much wood. The making of elaborate joints has also a tendency to cause the timber to split, for which reason dove-tailing or wedge-shaped joints are undesirable.

When the sides are unsafe, lagging or plank-sheathing should be placed between the barring and the sides

of the shaft, especially if the barring is not placed flush, set with set.

"English" and "German" Tubbing as used in Hand-Sunk Shafts.—The so-called English tubbing, consisting of small segments supplied in the rough, and, when erected, their joints being, as already described, wedged with wood, is still largely used; but the "German" type of tubbing (Figs. 99 and 100), made in larger segments, often 5 feet high, with thin sheet lead between the joints, and bolted together, is becoming increasingly popular. These segments are carefully machined, so that the surfaces of the vertical and horizontal flanges may be perfectly parallel, and the facing for the bolts in the bolt-holes is milled and tapered towards the inside, leaden washers being used, as shown in the section, Fig. 99.

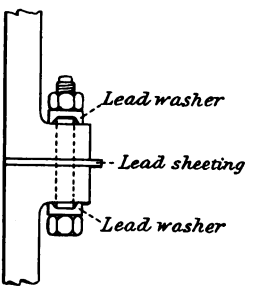


FIG. 99.—Detail of Joint in German Tubbing.

Where the ground is hard enough to stand for some time—as, for instance, when sinking through the Triassic or Permian sandstones or the Magnesian limestone—wedging curbs may be put in, and the tubbing erected thereon; the object of the curbs being the transference of the pressure of the rings to the rock, sometimes a great number of these are necessary within a comparatively short distance, and, as will be shown, the cost of putting them in (see Costs, page 178) is very considerable. The height to which the tubbing can be carried from any one curb before the insertion of another is governed by the stability of the rock and the quantity of water in the fissures of the same. Sometimes two, or even three, curbs are set one on top of the other.

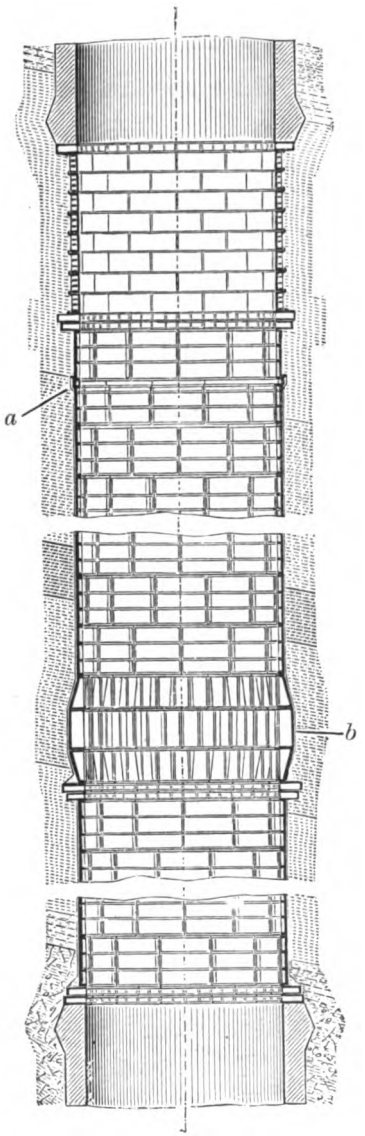


FIG. 100.—German Tubbing of Shaft, showing (*a*) Stuffing Box, (*b*) Corrugated Tubbing.

The Germans sometimes adopt a stuffing-box composed of two rings of tubbing segments, made to overlap and telescope to a certain extent (Fig. 100, *a*), the object being to obtain a certain amount of mobility and equalise the difference in height without having to put in "making up" or short segments of tubbing or rings.

Suspended Tubbing.—When sinking by hand through loose ground, it is advisable to protect the sides by inserting the tubbing as the work of excavation proceeds, which may be done by suspending the sections from those above by means of bolts. The manner in which this is done is shown in Figs. 101 and 102. Messrs Haniel & Lueg were the first to introduce this mode of tubbing, and have been very successful in applying it.

Corrugated Tubbing.—Corrugated iron tubbing is sometimes used on the Continent to afford a support for the shaft in places where there is not sufficient room to put in a wedging curb. At Eygelshofen (Dutch

Limberg), when sinking a shaft by the Gebhardt and Koeing congelation process (see page 253), the form of tubbing shown in Fig. 103 was resorted to, as, owing to the deviations in the bore-holes, there was not sufficient space available for laying the curb within the area protected by the frozen wall, and water in the disturbed Coal-Measures below the wall prevented any attempt being made to place the curb there. It was therefore decided to lay a supporting ring, the external diameter of which should be little in excess of that of the shaft tubbing,

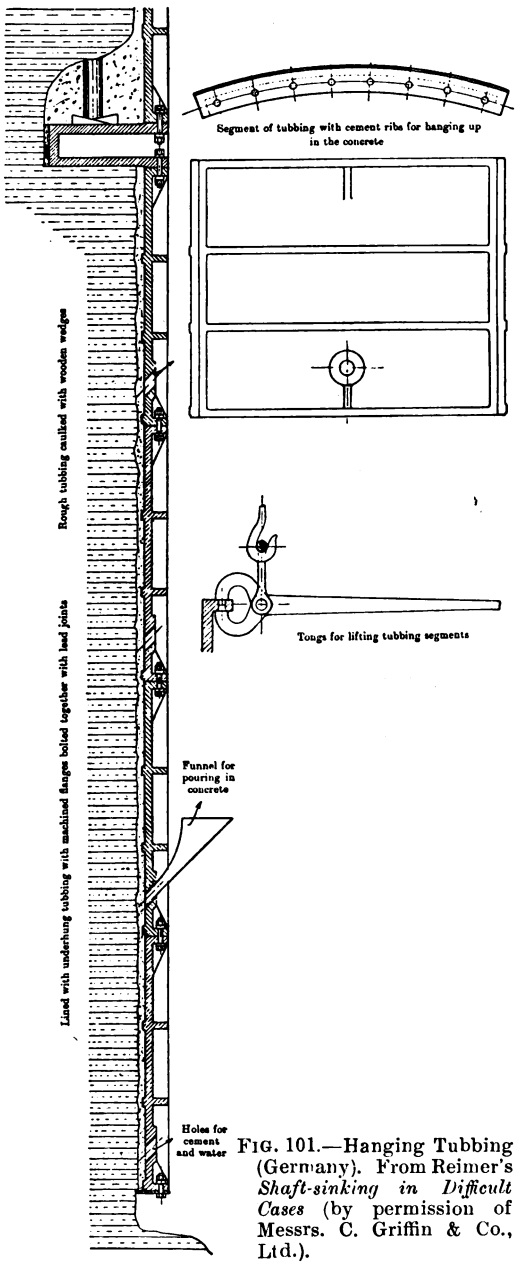

Segment of tubbing with cement ribs for hanging up in the concrete
Rough tubbing caulked with wooden wedges
Tongs for lifting tubbing segments
Funnel for pouring in concrete
Lined with underhung tubbing with machined flanges bolted together with lead joints
Holes for cement and water

FIG. 101.—Hanging Tubbing (Germany). From Reimer's *Shaft-sinking in Difficult Cases* (by permission of Messrs. C. Griffin & Co., Ltd.).

and allow of its being placed within the protected area, and have sufficient hold to sustain the entire weight (608 tons) of the tubbing. Two rings of corrugated tubbing, each 5 feet high and 17 feet in diameter (Fig. 104), were laid on a wooden curb at a

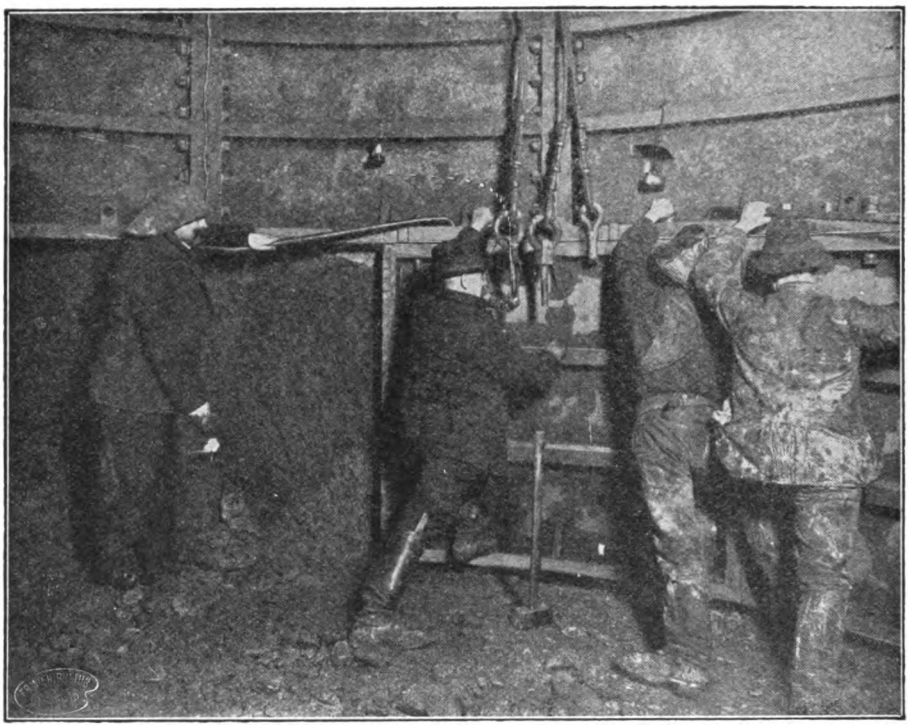


FIG. 102.—Putting in a Segment of Hanging Tubbing (Haniel & Lueg).

depth of 336 feet from the surface, the space of from 7 to 10 inches between the tubbing and the shaft being filled with rammed concrete, treated with 20 per cent. solution of calcium chloride, to keep it from freezing.[1]

Several other forms have been employed in similar

[1] *The Colliery Guardian*, June 12 and August 7, 1903.

instances, those shown in *b*, *c*, *d*, Fig. 105, having been used by the Schalker Gruben and Hüttenverein in sinking by the freezing process at Empelde, near Hanover, in

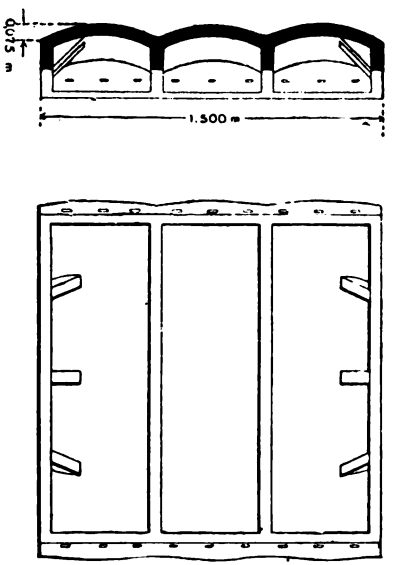


FIG. 103.—Corrugated Iron Tubbing.

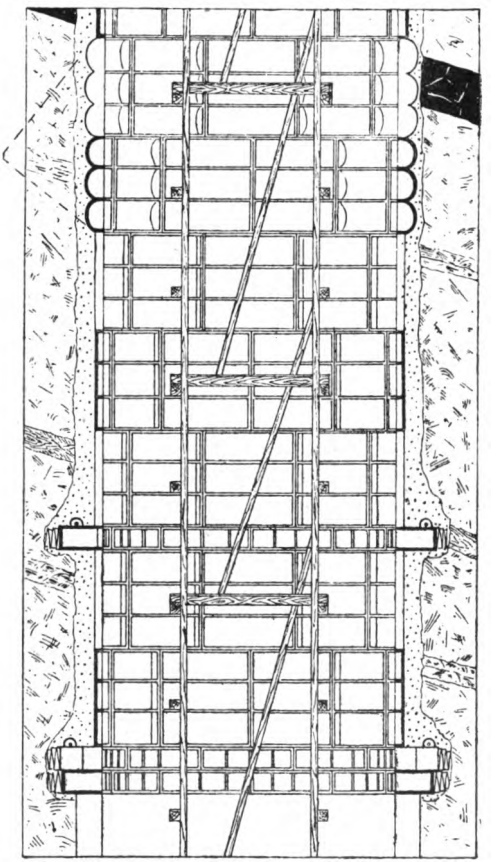


FIG. 104.—Corrugated Iron Tubbing in a Shaft at Eygelshofen.

1899, and that in *e* (same makers) in a shaft at Karlingen in 1890; *a* represents the type first mentioned.

Stress on Tubbing.[1] — Accumulator hydraulic

[1] For further particulars in respect to this subject the reader is referred to a paper read by Oberingenieur Reimer at the meeting of the German Mining Association at Dortmund.

presses were first applied to driving down shaft tubbings in 1895 at the sinking of the Rhein-Preussen Shaft No. III., since when the method has met with very considerable success (see page 205). The Hugo I. shaft at Holten, for instance, was sunk by this process to a depth of 100 metres in seven months. However, in the latter case the iron tubbing, which was 0·70 mm. thick, cracked.

It is not easy to account for the cracking of very strong tubbing at shallow depths, indicating as it does a

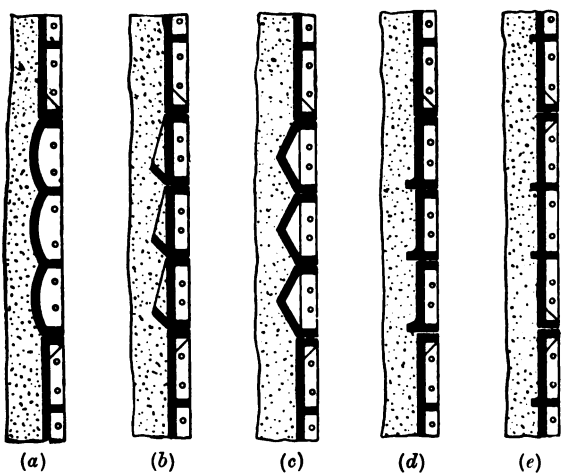


FIG. 105.—Five Types of Corrugated Iron Tubbing.

pressure far above that due to the head alone. Thus in the case of a shaft of only 4·5 metres internal diameter and 31 metres depth, longitudinal cracking is mentioned by Herr Reimer as having taken place, and the present writer saw a somewhat similar instance in the United Kingdom this year. The shallow depth shows that it cannot be accounted for by static pressure, and it would seem that Reimer is in all probability correct in his argument, which is to the effect that, seeing that the strata sunk through are composed alternately of layers of loose sand

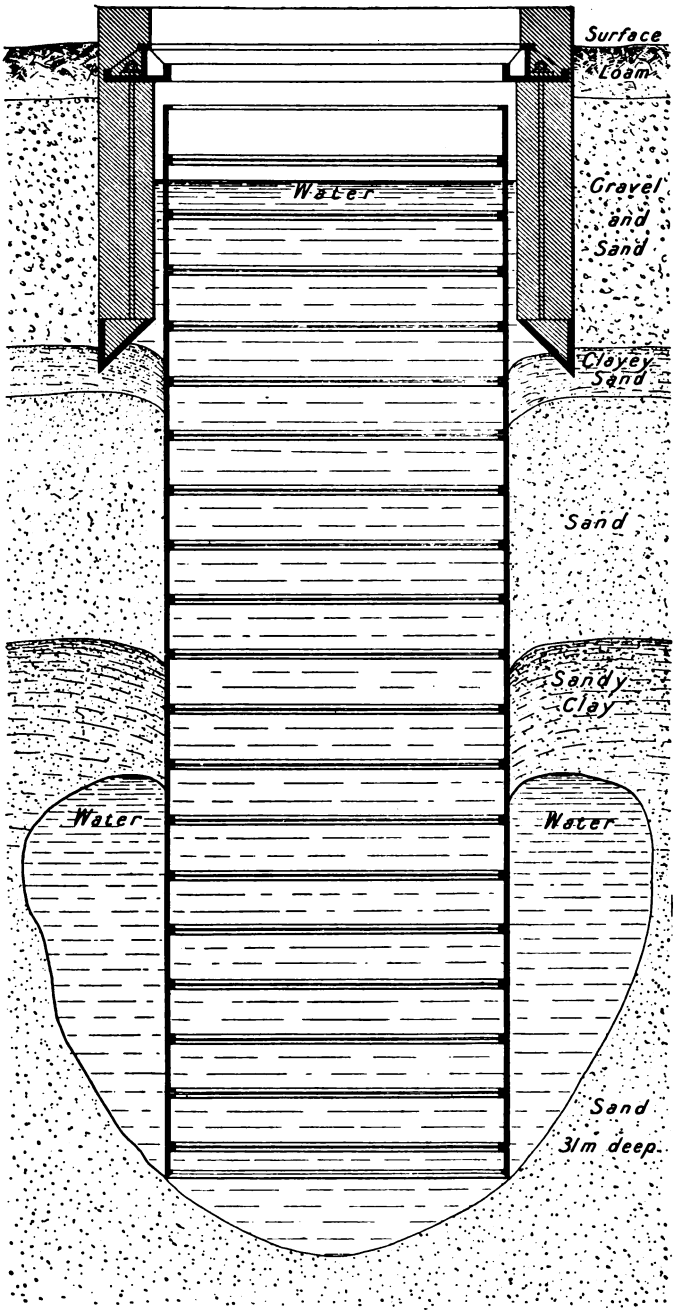


FIG. 106.—Sinking Drum with Washed-out Hollow Chamber. From Reimer's *Shaft-sinking in Difficult Cases* (by permission of Messrs. C. Griffin & Co., Ltd.).

and more solid clayey bands, caving-in is liable to take place, due to extraction of the ground within the shaft, and that when a fall of roof of a cavity happens, it would drive a large quantity of water high up into the shaft, causing it to strike a heavy blow on the iron walls; and he goes on to say: "The blow delivered by the mass falling from the sloping roof of the cavity against the shaft walls is mostly noiseless, owing to the materials being immersed in water, and consequently, unless there is a surface subsidence, all that is noticed is a sudden rise of the water-level in the shaft" (see Fig. 106). He makes a rough estimate of the force so generated in an imaginary case. Supposing a radial width of such a cavity to be 4 m., and height of space filled with water 10 m., and the roof fall to be one-quarter of the area (say a length of 6 m.), the falling layer being 5 m. thick, the volume of material subsiding would be 120 cub. m., which would produce an excess of pressure of about 120,000 kilogs., and, assuming the fall to occupy two seconds of time if occurring in water and not in air, we have for a fall of 10 m. a liberation of energy equal to—

$$(120{,}000 \times 10) \div (2 \times 75) = 8000 \text{ h.p.}$$

which gives some idea of the enormous strain the tubbing may have to sustain.

CHAPTER VI

THE DRAINAGE, VENTILATION, AND LIGHTING OF SINKING PITS

Drainage by Kibbles.—Unless the water "made" in the sinking pit is considerable, it may be satisfactorily dealt with by drawing it to the surface by means of water-buckets, variously termed water-kibbles, water-

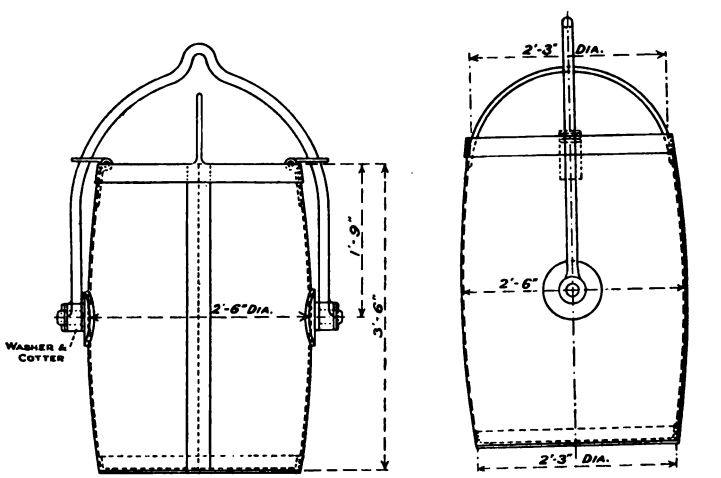


FIG. 107.—Water-Barrel commonly used in Sinking Pits.
(Messrs. J. Cook, Sons & Co., Ltd.)

hoppits, water-barrels, or kettles, several types of which are shown in Figs. 107, 108, 109. That illustrated by Fig. 108 is worthy of particular notice as having recently been successfully employed in some South Wales sinkings, at one colliery enabling the sinking to be continued until the wedging-curb bed was reached, without the

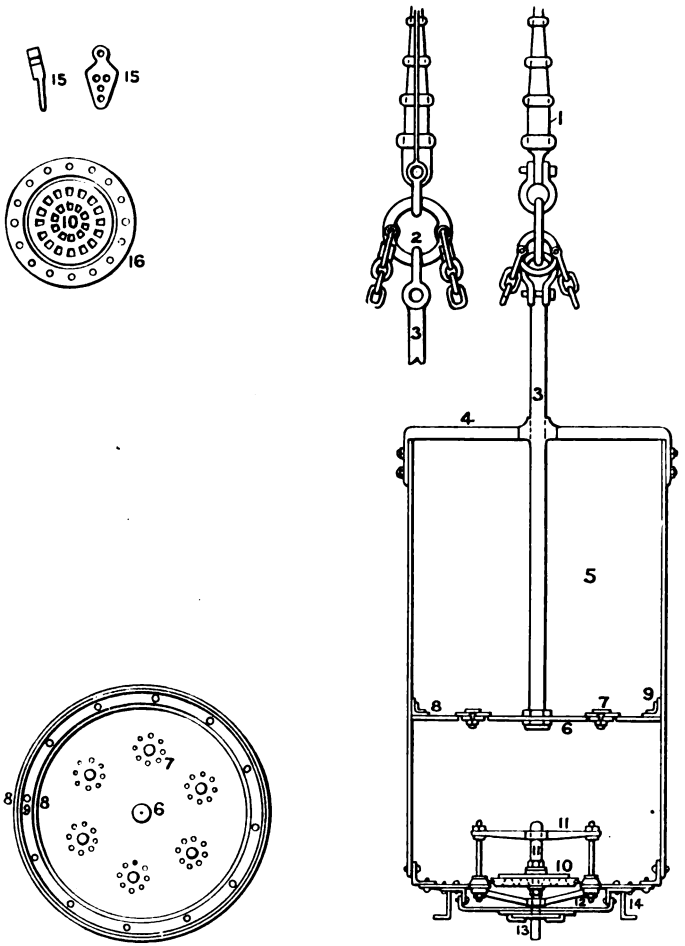


FIG. 108.—Drainage Kibble designed by Mr. John Swinburne.

1. Cap with Hoops.
2. Self-adjusting Links and Shackles.
3. Piston Rod, 3″×3″ section.
4. Guide Bar.
5. Cylinder.
6. Piston.
7. Air-Valves with Indiarubber Covers.
8. Leather Packing.
9. Junk Ring.
10. Grated Valve of Brass, with Indiarubber Cover.
11. Valve Spindle with Guide Bar and Pillars.
12. Perforated Shield, to prevent choking of valve by large stones.
13. Lid hinged to let out small gravel.
14. Channel Iron Stands for Barrel to rest on.
15. Hangers for Chains, Attachment made fast with Counter-sunk Rivets.
16. Valve Seat, Cast-iron Faced.

introduction of pumping appliances, and drawing the water, during the process of erecting the tubbing, through trap-doors in the scaffolds. It holds 440 gallons, and

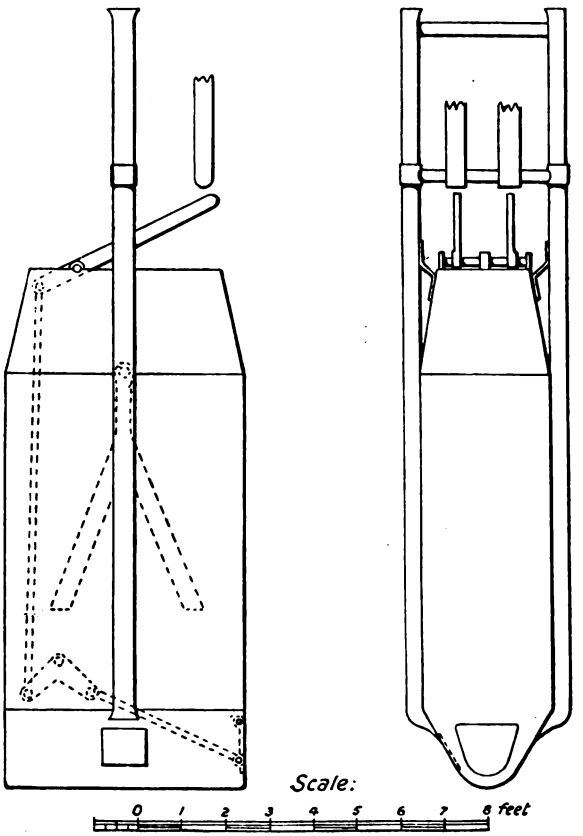


FIG. 109.—Type of "Bailing Tank" largely used in Sinking Shafts on the Rand.

is the invention of Mr. John Swinburne of the Nantyglo and Blaina Steam Coal Collieries.[1]

The action is as follows:—When the kibble touches the bottom of the shaft the valve rises and the water fills the space below the piston, the air escaping

[1] See the *Journal of the British Society of Mining Students*, vol. xxi. p. 160.

through valves in the piston. At the moment of touching the engine is reversed, moving the piston and causing it to draw up more water, so rendering the bucket an effective drainer in even shallow water. On being wound up, the engine is again reversed and the water discharged. The various parts are indicated in the sketch.

During the sinking of the deep-level (gold-mine) shafts on the Rand, "bailing tanks," as water-kibbles are there termed, are extensively used, the capacity varying from 300 to 1500 gallons, the type that has been found most convenient being illustrated in Fig. 109.[1]

Pulsometers.—The drainage of sinking pits is sometimes carried out by means of pulsometers; when this is the case they are usually coupled up in the manner shown in Fig. 110, or the discharge of the lower pump can be taken into the suction-pipe of the upper one (Fig. 112). The more general plan is, however, to fix the upper pump permanently, with its suction-pipe laid into a small tank supported on shaft timbers, the lower pump only being suspended by chains and lowered down as the work of sinking proceeds, and discharging into the tank.

A sinking job has been carried out with pulsometers where the quantity of water raised was from 130,000 to 140,000 gallons per hour, and where the steam was carried from boilers 350 feet away from the mouth of the shaft.

The pulsometer consists of a single casting called the body, which is composed of two chambers AA (Fig. 111) joined side by side with tapering necks bent towards each other and surmounted by another casting

[1] "Sinking, Development, and Underground Equipment of Deep-level Shafts on the Rand," by A. E. Pettit, *Trans. Inst. M.M.*, February 1906.

called the neck, J, accurately fitted and bolted to it, in which the two passages terminate in a common steam chamber, wherein the ball valve, I, is fitted so as to be capable of oscillation between seats formed in the junction; downwards, the chambers AA are connected with the suction passage C, EE being the inlet or suction valves, FF discharge valves (may be one or two) leading to the rising main D, B an air-chamber, HH hinged covers closing the suction and discharge chambers, GG guards controlling the amount of opening of the valves EE, and K is the steam-pipe.

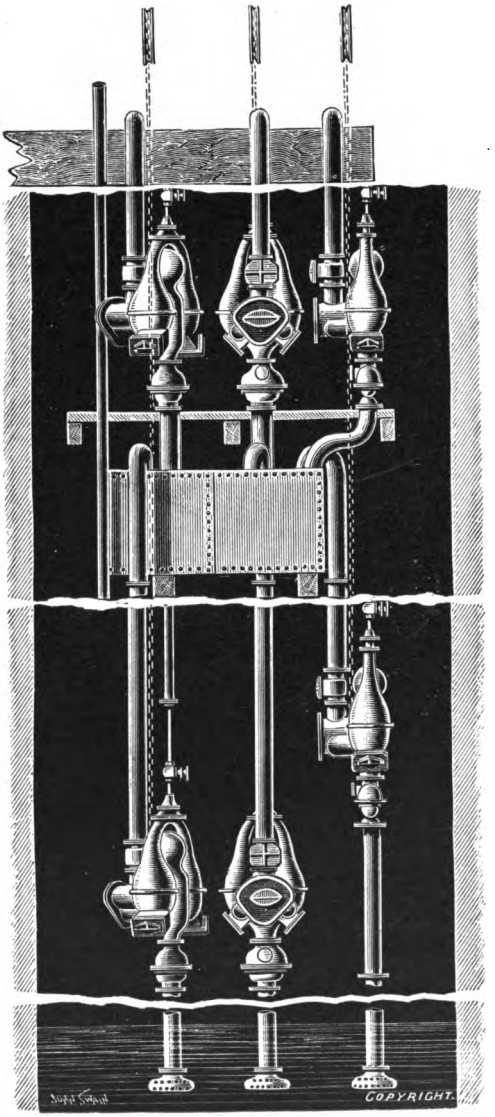


FIG. 110.[1]—Arrangement of Pulsometers in a Sinking Pit.

The pump being filled with water, either by pouring it through the

[1] Figs. 110, 111, and 112 are reproduced by permission of the Pulsometer Engineering Co., Limited

plug-hole in the chamber, or by drawing the charge, is ready for work. Steam, being admitted through the steam-pipe (by opening to a small extent the stop-valve), passes down that side of the steam neck which is left open to it by the position of the steam ball, and pressing upon the small surface of water in the chamber which is exposed to it, depressing it without any agitation, and consequently with but slight condensation, drives it through the discharge opening and valve F into the rising main. The moment that the level of the water is as low as the horizontal orifice which leads to the discharge, the steam blows through with a certain amount of violence, and being brought into intimate contact with the water in the pipes leading to the discharge chamber, an instantaneous condensation takes place, a vacuum being in consequence so rapidly formed in the just emptied chamber that the steam

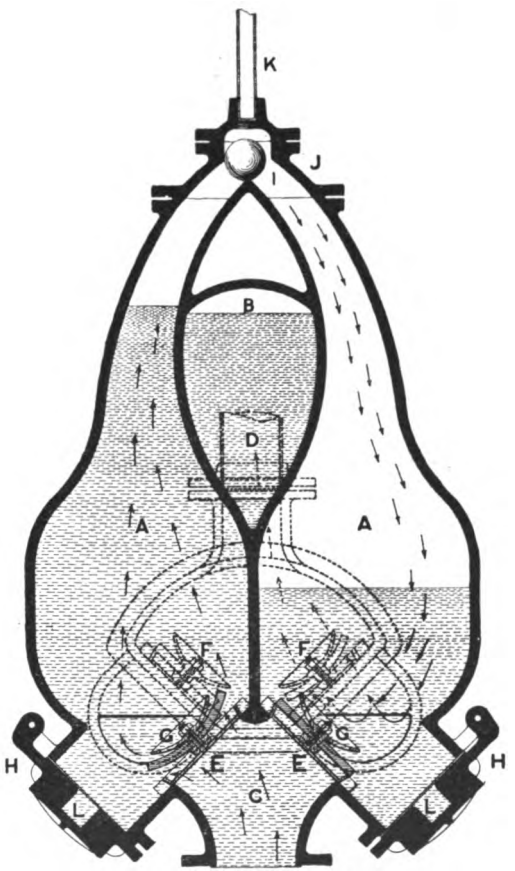


FIG. 111.—Explanatory of the Action of a Pulsometer.

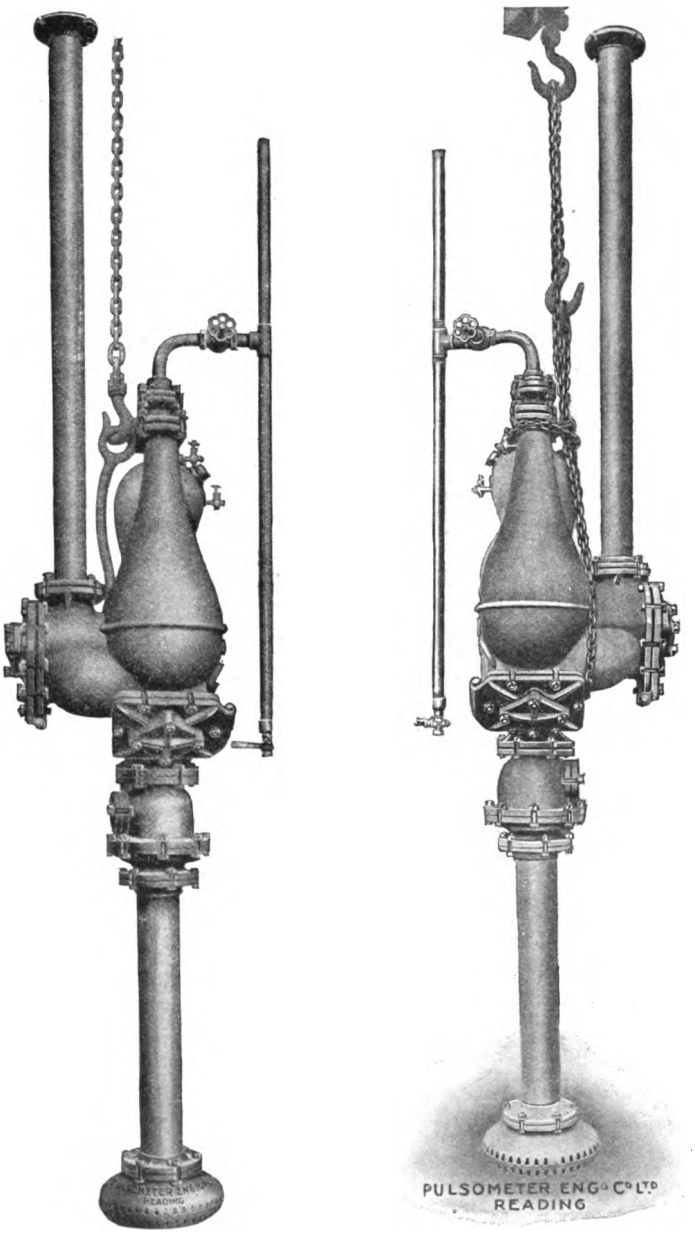


FIG. 112.—Single Pulsometer as slung in a shaft.

ball is forced over into the seat opposite to that which it had occupied during the emptying of the chamber; the further admission of the steam into this side is therefore prevented, and the vacuum being completed, the water rushes in through the suction-pipe, lifting valve E, and rapidly fills chamber A. The change is so rapid that, even without an air-vessel on the delivery, but little pause is visible in the flow of the water, and the stream is, under favourable circumstances, very nearly continuous. The air-cocks are introduced to prevent the too rapid filling of the chambers on low lifts. In the majority of these pumps grid valves are employed.

The pulsometer, though not so economical as high-class piston pumps, which work with a variable cut off, is a useful pump, and will raise water from 1 to 100 feet, or, when coupled together, from 300 or 400 feet. It possesses the following advantages:—

(*a*) It is not subjected to the same wear and tear as other pumps.

(*b*) The working parts (the valves) can be readily and cheaply renewed.

(*c*) It is not necessary to employ skilled labour to attend to them.

(*d*) No oil, tallow, or leathers are required.

(*e*) It will work equally well suspended by chains as when fixed, and can be used whilst being lowered.

(*f*) Semi-liquids, or gritty and muddy water, can be pumped by it—that is, water containing upward to 50 per cent. of mud or sand.

(*g*) Compactness.

(*h*) There is no exhaust steam to deal with.

(*i*) All the moving parts are inside the pump.

It has been claimed for the pulsometer that it will work with exhaust steam or steam at 3 to 4 lbs. pressure, up to steam at a pressure of 100 lbs. or even higher. It is said that it will pump water of a temperature up to 180° F. Pulsometers have been known to work at a depth of from 50 to 90 feet under water.

Reciprocating Steam Pumps, Beam Engines.—If the feeders of water are very large and the shaft is "hand-sunk"—that is, if drainage has to be resorted to, instead of adopting the Kind-Chaudron, the freezing, or some other process, in which cases drainage during sinking is not necessary—it is usual to have recourse to steam pumps proper.

In this respect the Cornish sinking set has a remarkable record. For instance, in the sinking of Murton Colliery, one of the South Hetton pits in the county of Durham, in 1842, whilst passing through the quicksand at a depth of 73 fathoms from the surface, it is estimated[1] that no less than 10,000 gallons of water per minute were being raised; there being employed for this purpose—

Three engines of 350 H.P. each	1050
Two engines of 130 H.P. each	260
Total H.P.	1310
Or, including winding-engines	1478 H.P.

the water rising through eighteen columns of pipes of 19½ inches diameter and nine of 16 inches diameter. Eventually the whole of the feeders were effectually

[1] The sinking of this pit commenced on February 19, 1838, and on June 26, 1839, the sand feeders "burst away from the bottom of the shaft, throwing up with gigantic force 4 feet of strong limestone which intervened between the bottom of the shaft and the top of the sand."—*The Winning and Working of Collieries*, by Mathias Dunn, 1852, second edition, p. 69.

stopped back by metal tubbing of from ¾ inch to 1¼ inch thick; the Hutton, or lowest seam sought for, being reached April 15, 1843.

Mr. Prest, the able mining engineer of the Horden Collieries, some miles to the south of the undertaking described above, has recently (1903) successfully sunk two shafts by ordinary hand-sinking and pumping, having had great difficulties to contend against, and has contributed an interesting and valuable account of the exploit to the *Transactions of the Institution of Civil Engineers.*[1] At the sinking, the maximum volume of water pumped by a pair of 30-inch bucket lift pumps, with 6 feet stroke, was 6100 gallons per minute, from a depth of 95 yards; but the average feeders pumped out of the two shafts between 23rd of September and 26th of November 1903 amounted to about 9230 gallons per minute.

Design of a Sinking Set for Heavy Pumping.—Mr. Prest gives the following notes on the design of the 30-inch bucket lift pumps which he used:—

"*Quadrants.* — Of best mild steel, 1 inch thick. Horizontal plates on one quadrant prolonged at one end beyond the centre to take counterbalance-weights, an angle-bar being riveted on the top edge to receive the balance-weights. Ends of plates strengthened by a plate. Also horizontal plate in one piece. Vertical plates stiffened at the top end by a plate riveted on the outside. Vertical plates extending to bottom of horizontal plates, and tied together with a plate extending upwards from the bottom along the horizontal plate. Pumping ends also stiffened by plates. All

[1] "Shaft-sinking at the Horden Collieries, South-East Durham," by J. J. Prest, M.Inst.C.E., *Trans. Inst. C.E.*, vol. clxxiii. pp. 42-64.

these plates well riveted together. The two sides of the quadrants held together by distance-pieces of cast-iron and bolts as shown. Cast-steel centre-piece faced and bored to take centre shaft, and bolted to plates on each side. Diagonal stays, eight in number, of best forged mild steel, having eyes at the top and bottom ends, bored out to take the pins, and fitted with distance-pieces and bolts.

"*Shafts, Pins, and Plummer-Blocks.*—All of best forged steel, and removable for repair or renewal without disturbing the quadrants. Centre shaft turned to 12 inches in diameter, and 6 feet 2 inches long over all; bearings 10 inches in diameter and 15 inches long. Plummer-blocks of cast-iron, fitted with top and bottom gun-metal bearing brasses.

"*Side Connecting Rods to join Quadrants.* — Pumping quadrants connected by two side rods made with butt end straps, brasses and keys bored out to 8 inches to take outer end of pins. Rods smithed and machined at the ends.

"*Hanging Rods.* — About 15 feet 6 inches long from centre to the bottom end, $2\frac{1}{4}$ inches thick where the keys pass through, $1\frac{3}{4}$ inch below the top bolt, and tapered down to $\frac{3}{4}$ inch at the bottom. Plates 9 inches wide, and distance between to suit 12-inch spears. Plates are holed zigzag to take $1\frac{3}{8}$-inch square-necked bolts every 14 inches to each side alternately. Top brasses only to bearings, the lower part being of cast-iron; at top and bottom of bearing a plate 1 inch thick, the whole being of the best mild steel, properly forged and smithed.

"*Wet Spear Plates.*—Of Siemens-Martin best mild steel, 18 feet long, 9 inches wide, and 1 inch thick, holed similar to the hanging rods.

"*Ground Spear Plates.*—15 feet by 7½ inches by 1 inch.

"*Working Barrels.*—Of cast-iron, 2½ inches thick when bored, and perfectly circular. Each fitted with gun-metal liner ½ inch thick, reducing the diameter to 30 inches.

"*Cast-iron Bucket Pieces.*—10 feet long and 2¾ inches thick in the plain part. Doorway flange 2¾ inches thick, and strong ribs between each bolt-hole extend from under outside edge of the flange round the body part, joining flange under outside edge, opposite; depth of door-opening allows the exit of bucket with sword attached. Lower flange fits spigot of working barrels, and upper flanges suit rising main pumps.

"*Cast-iron Clack-Pieces.*—2¾ inches thick above clack seat and 2¾ inches below. Clack seat bored out level with bottom of door-opening. No shoulders above clack seats to prevent clack from going into its seat readily when lowered from top of pumps.

"*Bucket and Clack Doors.*—Of cast-iron, 3¾ inches thick, strengthened on the front with strong arched ribs, extending across from bolt-hole to bolt-hole, faced for joint to suit clack-piece opening.

"*Cast-steel Wind-Bores.*—30 inches in diameter inside, 1½ inch thick in the plain part and rounded down to a point, as usual for sinking sets. Snore-holes 2 inches in diameter, with usual taper from inside, and rimered out. Flange faced to fit the clack-piece.

"*Bottom-Rods for Wet Spears.*—Of best forged iron. U part 14 feet in length, with holes and bolts as in the hanging rods. U plates 1¾ inch thick at the neck and ¾ inch at the ends. Four ground spear bottom-rods with U plates meet the ground spears.

Bottom-rods $4\frac{1}{2}$ inches square for 34 feet in length, and provided with keys to take hanging clamps.

"*Buckets and Clacks.*—Of cast-iron, turned, planed, and fitted with wrought-iron falls.

"*Fish-head.*—Of forged iron to fit clack bows, and the offtake joint to fit bottom-rods.

"*Rising Main Pipes.*—Of best mild steel plates, $\frac{3}{8}$ inch thick, and 32 inches in diameter inside (circumferential seams single-riveted, longitudinal seams double-riveted, and all inside rivets flush and rounded so as to permit of a hoop $31\frac{1}{2}$ inches passing clear down the inside). Thirteen pipes for each set of pumps, each 18 feet in length over the flanges, properly caulked and tested to 450 lbs. per square inch, the working pressure being about 300 feet head. Joints formed with a steel angle riveted on to the pipes, caulked and faced, and fitted with all necessary bolts and nuts. Pumps coated twice with Dr. Angus Smith's composition.

"*Hogger Pumps.*—Of steel plate, $\frac{1}{4}$ inch thick, 32 inches diameter inside. Flanges fit the foregoing pumps."

Specification of Pumps.—The following specification, relative to sinking pumps at a colliery with which the author was connected some years ago, may be of value, and serve as a guide to young mining engineers :—

Specification of Two Sets of 20-inch Pumps, viz. One Standing Set and One Sinking Set, for . . . Colliery.—Standing set to consist of one wind-bore, one clack-piece, one working barrel, one bucket tree with seventeen common pumps, 21 inches diameter in 10-feet lengths, according to drawings and dimensions marked thereon. Wind-bore of standing set to have a flat bottom, to stand on a metal bunton, and to be 7 feet long, and perforated with 3-inch holes 3 feet from the bottom ;

holes to have ¼-inch taper in thickness of metal and be properly rimed out. Clack-piece to be 10 feet long; working barrel to be 8 feet long, and 20 inches diameter when bored; bucket tree to be 10 feet long. All joints to be spigot and faucet, as shown on tracing. Wind-bores, clack-pieces, working barrels, bottom of bucket tree joints to be faced, ten holes to be in each joint, 2 inches by 1½ inch. Bottom pieces of sinking set to be same size as those of standing set, excepting the working barrel, which is to be 12 feet long and 20 inches diameter when bored, and eighteen common pumps in 10 feet lengths. Clack-piece of sinking set to have two bands, as shown on tracing, to admit of clamps 10 inches broad for suspending the set. The working barrels of both sets to be cast as hard as can be bored. The whole to be tested by hydraulic pressure to 600 lbs. per square inch, and to be completed to the satisfaction of the party appointed to inspect the same, who shall have power to condemn any of the castings which may appear to him defective, the same to be replaced at the expense of the Contractor.

The metal to consist of hæmatite . . .	One-third
Good "coal" iron	,,
Good old, or scrap, iron	,,

All goods to be delivered at the . . . Colliery. The whole to be completed according to the plan and specification of the . . . Coal Company or their Agents. All tenders to be delivered to . . . . . Address . . . . .

Putting in a Pumping Set.—The manner of putting a set of pumps for a beam engine into a shaft is as follows:—

The lowest pump or wind-bore being placed at the bottom of the pit, immediately beneath the end of

the beam, and the rest of the pumps, *i.e.* clack-piece, working barrel, bucket door-piece, common pump, and hogger-piece, being placed vertically upon each other in order, by means of crabs, and temporarily steadied in shaft, are collared to what are termed "ground spears," one on each side of the set by means of iron collarings or hoops. The joints of all the pumps should be accurately faced, so that their drawing together by the pump bolts will be sufficient to make a water-tight joint. At the top of the ground spears is one of a pair of five or seven-fold blocks, called ground-blocks, the other being placed on buntons at the top of the pit; through these blocks a pair of ropes are rove, the surface end of each being attached to a ground-crab; these ropes, which are called "ground ropes," are usually 7 inches or 8 inches in circumference (varying according to the weight of the set). After the "set" has been properly placed, the spears are put in by the crabs and attached to the engine. The clack is then set in its place, the bucket (which resembles the clack) attached by means of the bucket-sword to the bottom rod of the spears, and the clack and bucket doors screwed up to their places, and the engine set to work.

Suspending of a Sinking Set.—Fig. 113 indicates the manner of suspending a sinking set in a shaft. The illustration represents the sinking set in the No. 2 pit at Claravale Colliery, on the banks of the Tyne, which was sunk a few years ago (commenced in 1890) by the eminent mining engineer, Mr. J. B. Simpson. For some time feeders of water, amounting to 2000 gallons per minute, had to be dealt with. A lifting set of 18 inches diameter and 6 feet stroke was attached to the winding-engine which worked the pumping quadrant. The pumps were hung in the shaft by hanging-spears of

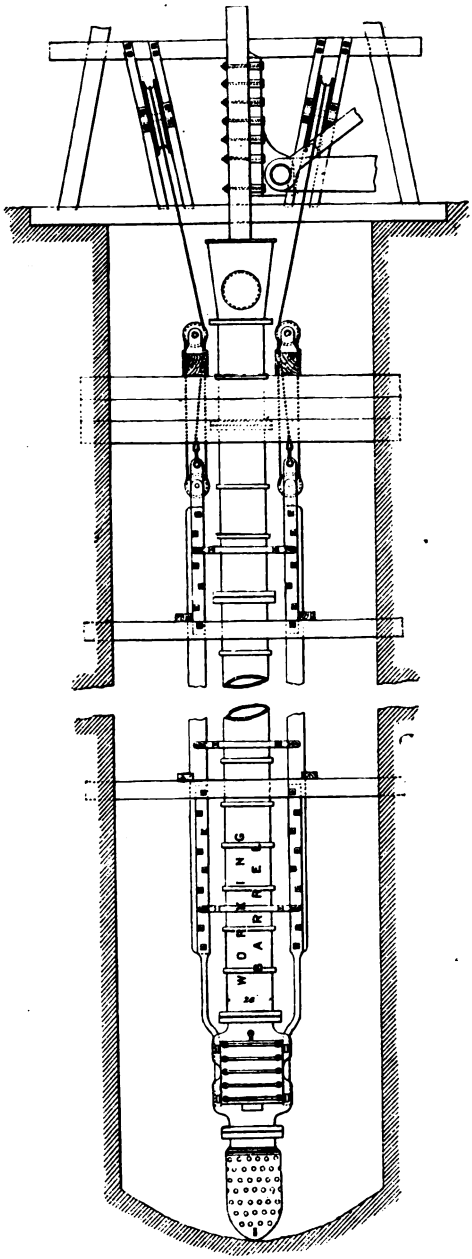


FIG. 113.—Manner of Suspending and Lowering a Sinking Set in a Shaft.

pitch pine, 8 inches by 6 inches in 30-feet lengths, attached to a ground-crab by a hemp rope, 3 inches in diameter, passing over the pulley blocks as shown in Fig. 114.[1]

Types of Sinking Pumps Worked from the Surface.—Nothing can be simpler or better under ordinary conditions than the somewhat antiquated system of the horizontal engine, actuating quadrants on which spears are hung, the latter working in colmuns of pumps (pipes) in the shaft (Fig. 113). It might be, however, as in the case at Cadeby Colliery,[2] that the ground near the shaft is unfit to carry the heavy weight of a surface-stationed pump. There is this advantage in surface-

[1] For the use of this illustration the author is indebted to the Council of the Institute of Mining Engineers.

[2] *Trans. Inst. M.E.*, vol. iv. p. 199.

stationed pumping engines for draining sinking shafts—they can be used afterwards as the permanent plant for draining the mine. The types of stationary engines used to work spears are — (1) the Cornish Beam Engine; (2) the Double-acting Beam Engine (sometimes mis-termed the Cornish Engine), which is largely used in the north of England as a permanent pump; (3) Barclay's Engine, which has the advantage of economy of space; (4) the Rotatory Beam Engine, or Beam

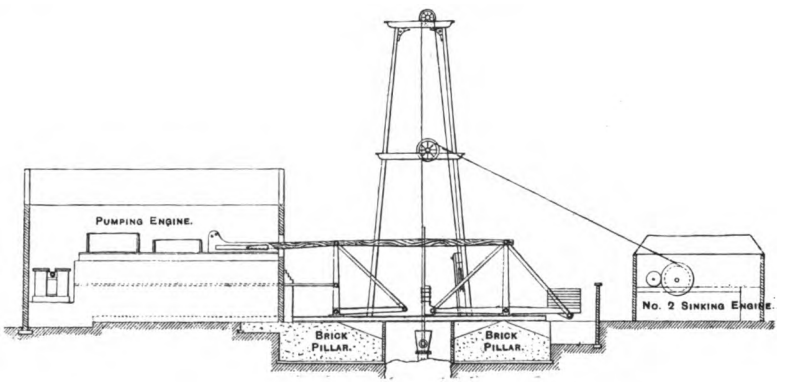


Fig. 114.—Sectional Elevation of a Pumping-Engine, Quadrants, &c.

Engine with fly-wheel; and (5) Davey's Compound Differential Pumping Engine, which has largely taken the place of the Cornish and the Double-acting Beam Engines, its special feature being the differential arrangement of the valve gear, whereby the working of the engine is regulated and kept under control in the event of any undue stress or breakage of spears, &c. It is an expansively-worked condensing engine.

Corrosive Water.—Mine water is sometimes very corrosive, though this is more frequently the case with water from the workings than that met with in sinking. The author once had to deal with some water which, passing through old wastes, contained as much as 1 per cent.

of sulphuric acid, and was very destructive to the valves of the pump raising it. Not only the valves but the rising main and other pipe connections suffer severely in some cases. In some Swedish mines the mains are lined with pine wood $\frac{3}{8}$ inch thick, the staves being held together by keys driven into the long, thin grooves made in the staves, as shown in Fig. 115, but the wooden linings are giving place to copper coating. It will be found advantageous where the water is very corrosive to line all the door pieces, pole cases, and matching pieces with $\frac{1}{2}$-inch sheet lead. A mixture of $4\frac{1}{4}$ parts lead, 10 parts copper, and 1 part zinc constitutes a good compound for lining pipes liable to be attacked by mineral waters, being the mixture adopted at the Santo Domingos Copper Mine (Portugal), but the rising main in this instance was internally lined with staves 1 inch thick, the ram being made of greenheart timber, hooped with thick copper hoops.

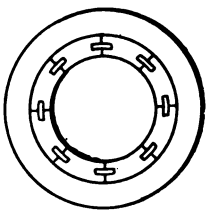


FIG. 115.—Internal Lining of Pumps with Wood.

Calculating the Size of Pump.—It is difficult, if not impossible, to determine in advance what sized pumping engines will be required for a sinking, for not only is the estimation of the probable quantity of water to be met with largely a matter of guess-work, but varies greatly during the sinking, and additional pumping power may be required at any moment if too small engines have been adopted. The following example, however, gives a ready means of determining the size of plunger which would be required to meet a given quantity of water. Suppose the quantity of water to be raised amounts to 3500 gallons per minute, and the depth is 1200 feet.

3500 gallons of water = 35,000 lbs.

Assuming an effective steam pressure of 90 lbs. per square inch, and a rate of ten strokes per minute, the length of stroke being 12 feet; the pump being double acting.

Then if D = diameter of plunger in inches,
G = gallons per minute,
L = length of effective stroke per minute,

$$D = \sqrt{\frac{G}{\cdot 034 \times L}} = \sqrt{\frac{3500}{\cdot 034 \times 10 \times 12 \times 12}} = 20 \cdot 7 \text{ ins.}$$

without allowing 5 per cent. for slip.

Another simple method is as follows:—

Gallons per minute ÷ speed of pump in feet per minute
= gallons delivered per foot of stroke;
and, taking 277·274 cubic inches in a gallon,
gallons per foot of stroke × 277·274 = cubic inches of water,

$$\frac{\text{cubic inches of water delivered per foot of stroke}}{12} = \text{effective area of plunger,}$$

effective area of plunger + area of piston rod = area of plunger.

Suspended Pumping Engines.—Hitherto, except in the case of pulsometers, the question of carrying out the drainage of sinking pits by means of pumping engines placed on the surface working the pumps in the shaft has been considered. In many modern sinkings, however, the drainage is performed by a composite apparatus, that is to say, a self-contained or direct-acting engine and pump slung in the shaft. Among some of the best known types—to mention a few—being the Evans, Cameron, and Denaby, which are steam-driven; and those electrical, the Knowles, Worthington, and Scott and Mountain.

The Denaby Sinking Pump.—Fig. 116 represents the Denaby sinking pump, as used in the sinking of the New Cadeby Colliery of the Denaby Main Colliery Company in 1889. The parts are fully explained by

the reference numbers. It will be seen that there are three hollow plungers *aa'b*, the upper two of which, *aa'*, are stationary, and over them slide barrels *cc*, which are connected to the steam piston at *d*. From the lower end of these barrels the bottom plunger *b* projects and works into a third barrel *e*, this and the first two barrels being actuated by the steam piston. Connecting rods *ff* secure the third barrel and the two stationary plungers to the steam cylinder; so there are two small barrels in connection with a large ram moving between the smaller rams and the large barrel, which are also connected. In the junction between the smaller barrels and the large ram there is a system of indiarubber disc valves which constitutes the delivery valves, and a similar system at the bottom of the large barrel which constitutes the suction valves. On the upstroke of the plunger *b*, the water flows into the lower barrel *e*, and the water in the hollow plungers *aa'* is forced into the rising main *g*. On the downstroke, the water in the lower barrel *e* is forced through the lower plunger *b* and the valves into the upper barrels *cc* and the plungers, and thence to the rising main *g*. It will be seen, therefore, that the pump delivers on both the up and down strokes, the principle being the same as that of the Armstrong pump, in which the ram is about half the area of the piston, the area of the two upper rams being about half that of the lower rams. Six of these pumps at work at the Cadeby sinking averaged, at one period of the sinking, 70,000 gallons per hour, each at a depth of 110 yards. This type of pump can be lowered down as the water recedes, and additional pipes added at the top.[1]

[1] For an account of the Cadeby sinking, see "The Pumping Appliances Used in the Sinking at the Cadeby New Winning," by W. H. Chambers, *Trans. Inst. M.E.*, vol. iii. p. 513.

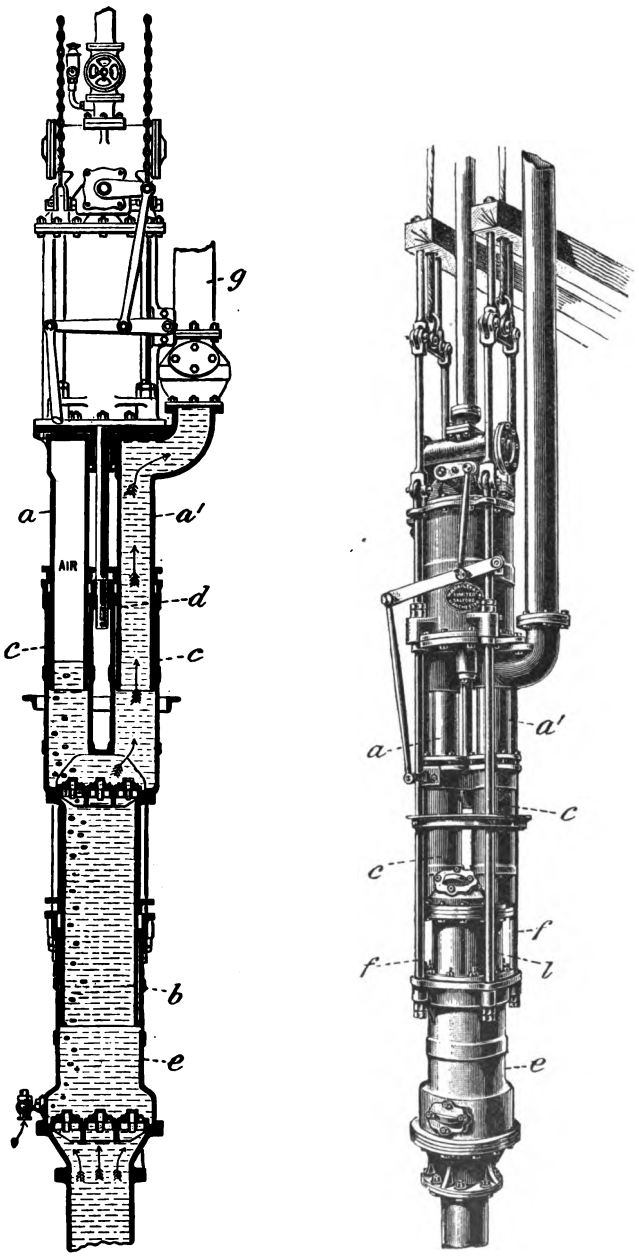


FIG. 116.—The Denaby Sinking Pump.

The Evans Sinking Pump.—Fig. 118 represents the Cornish direct-acting or "straight-line" type with Tonkins steam cylinder valve-motion, operated without tappets or lever motion, solely by the action of the steam. Thus, in Fig. 117, the steam is admitted by the ports K and M to the left of the small plunger G as the piston approaches the end of the stroke—moving say from

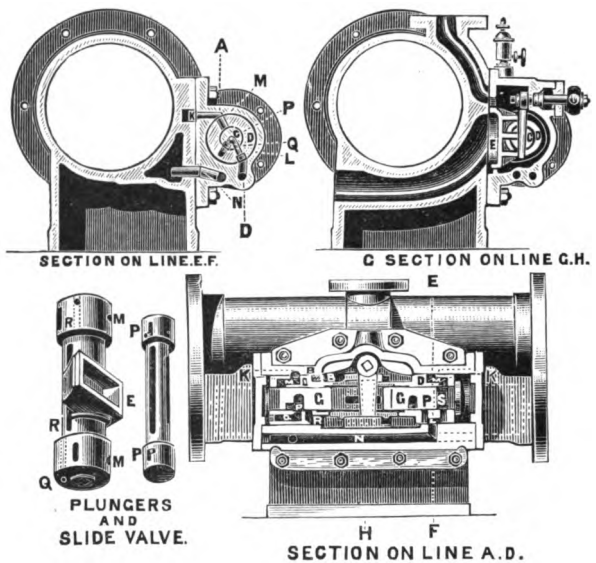


FIG. 117.—Details of "Cornish" Valve Gearing in the Evans Pump.

right to left—the plunger moving to the right, so that the right end of the large plunger D is placed in communication with the exhaust through the port N, and the left end with the interior of the steam chest B, from which steam is admitted through the ports R and Q, causing the plunger D and the common slide valve I to be carried to the opposite end of the steam chest and so reverse the motion of the main piston, a similar action taking place at the other end. Effective

cushioning of the plunger valves is secured by means of small ports, steam direct from the steam chest flowing in upon the end of the plunger towards the completion of its stroke. The exhaust steam from the plunger G passes through the small port S, and thence through the main exhaust N. Drain cocks are not necessary, as, the steam chest being placed on one side of the cylinder, and the bottom of the steam port being on the same level as the bottom of the cylinder, the whole of the condensed steam is carried out at every stroke of the piston. Fig. 118 shows one of these engines which is effective with heads up to 600 feet, and so arranged that it can be slung within suction distance of the water. It is double-acting and of the outside packed type, fitted with an improved differential ram, and with doors which render the valves easy of access. It is provided with an air-vessel and slinging eye-bolts for suspending. All the parts can

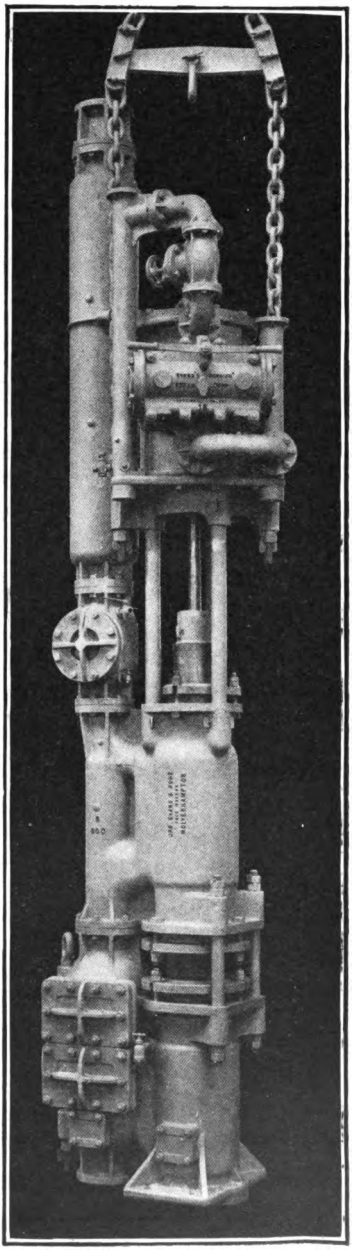


FIG. 118.—The Evans Sinking Pump.

be examined, and the ram, piston, or piston-rod be withdrawn without disconnecting any pipes, and there are no internal leathers or packings. The method

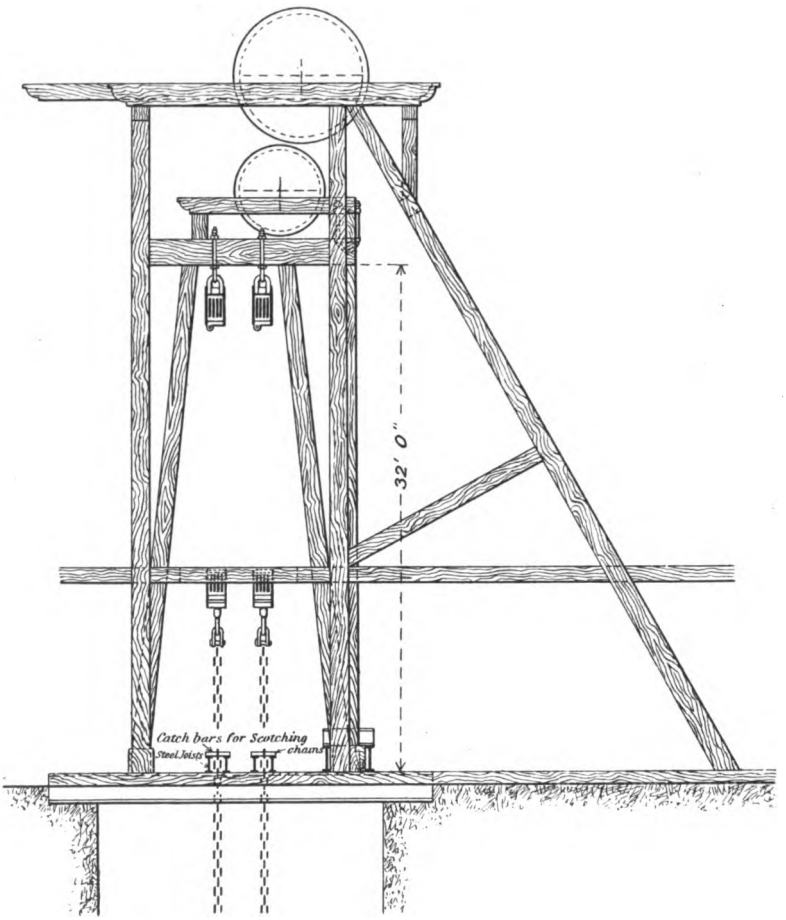


FIG. 119.—Manner of suspending Evans' Sinking Pump. Surface Arrangement.

adopted of suspending this pump at a recent sinking is shown in Figs. 119, 120.

Other sinking pumps are the *Cameron*—one of these vertical plunger sinking pumps placed in the mines of

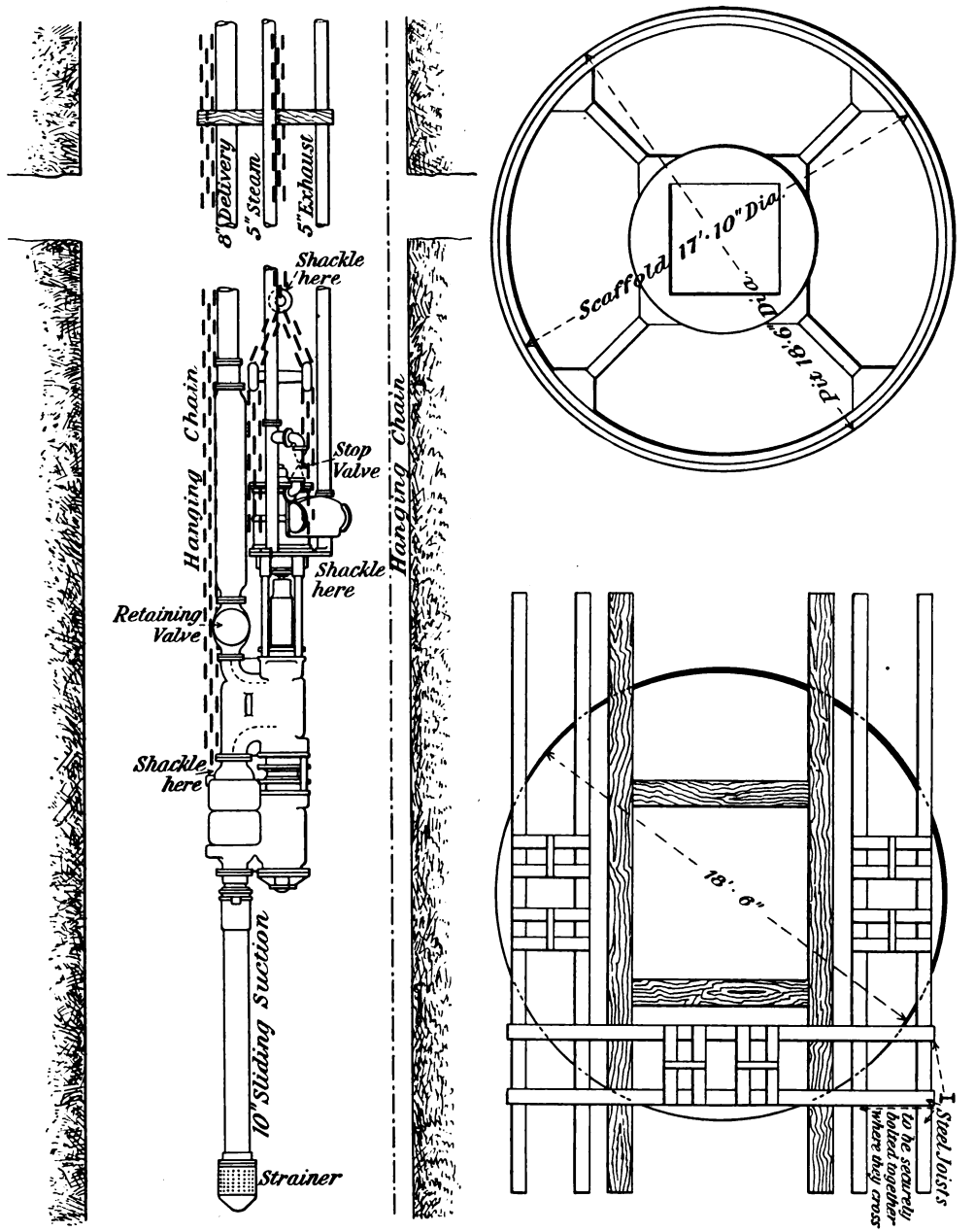


FIG. 120.—Manner of Suspending Evans' Sinking Pump in a Shaft, and Plans of Surface Arrangement.

the Thames Hauraki Goldfields Ltd. (New Zealand) having a capacity of no less than 1,500,000 gallons *per diem*—the *Knowles Improved Sinking Pump* (New York), and the "*Reading*" *Sinker* (Pulsometer Engineering Company), all of which are well-known and efficient pumps, of which and other types limitation of space precludes a description being given here.

Electrically Driven Sinking Pumps. — Electrical sinking pumps have of late years been extensively adopted in sinkings. These are chiefly of the turbine type, but there are several reciprocating electrically driven sinking pumps which are also doing good service, notably an American one, the Knowles vertical duplex sinking pump. Electrical sinking pumps have several advantages over steam pumps, especially as compared with steam pumps slung in shafts.

(*a*) They are steadier—they are subjected to less shock, especially those of the turbine type.

(*b*) Lightness and economy of space.

(*c*) There is no trouble and loss owing to condensation of steam, or with exhaust steam.

(*d*) They can be made to work under water for a longer time, and so long as the insulation is intact.

With the turbine pump, variation in respect of the head can be allowed for to some extent by the adoption of a multi-stage turbine so arranged that one or more of the impellers can be cut out, either by removing one of the impellers or by using a special by-pass. Head and quantity can be varied also by a corresponding variation in speed, and the quantity alone—at a certain loss in efficiency — by throttling the discharge. The Worthington Company make a pump which is directly connected to a three-phase induction motor, the

pump discharging into the two delivery pipes, which, together with suitable tie rods, constitute the frame necessary for supporting the weight of the pump and motor. Worthington turbine pumps have done remarkable work, one at Bliesenbach Colliery, near Ehreshoven, raising 220 gallons of water per minute against a head of 1100 feet; another at Preussen Colliery, Silesia, delivering 1320 gallons per minute against 1800 feet. Messrs. E. Scott & Mountain also supply a fine type of electrically driven centrifugal sinking pump. Fig. 121 shows one of the large pumps which they supplied for the Dover sinking, which were each capable of delivering 1000 gallons per minute against a head of 600 feet, and were driven by three-phase squirrel-cage motors of 300 H.P. running at 1440 revolutions per minute on 2000 volts.

There is no doubt that the squirrel-cage three-phase motor is the most suitable for such work, as the revolving parts are not connected electrically to any external circuit, the windings simply being short-circuited on themselves, and only low-tension currents are generated in these windings, and the whole construction lends itself to strength and reliability. The only disadvantage of the squirrel-cage motor is that a heavy current is taken at starting, and in the case of large pumps, as at Dover, it is recommended that a separately excited alternator be installed for running each pump, the pump motor being then switched on to the alternator before the latter starts, and as the alternator runs up to speed the pump runs up also. This arrangement has the further advantage that the speed of the alternator and engine can be adjusted so as to drive the pump at the speed most suitable for the actual head against which it has to deliver at the moment. With a centrifugal

pump designed for, say, 600 feet head, on 300 feet head the load on the motor will be excessive, and the pump will deliver considerably more than the specified amount of water. The only way to reduce the load on the motor would be either to throttle, which, uneconomical although it is, is frequently done, or alternatively, as suggested above, to reduce the speed of the motor (by reducing the speed of the engine and alternator) until the pump gives as much water against this head as would load the motor up to full load. The amount of regulation is not as great as might be expected, as, of course, the head of a centrifugal pump varies as the square of the speed, so that a slight difference in speed makes a good deal of difference in head.

Where a small sinking pump of, say, up to 100 H.P., is installed, and the generating plant is of ample capacity, it would probably not be worth while to put in the special arrangement suggested above, but the squirrel-cage motor has so many advantages as regards strength and freedom from breakdown, that it is still advisable to put it in, in spite of the difficulty in starting. Messrs. Scott & Mountain supply these smaller motors, with a compensator which enables a reduced voltage to be applied at the terminals of the motor, and reduces the amount of current required from the generating plant at the instant of starting. A squirrel-cage motor on starting up takes about three or four times its normal full-load current, and this current is also at a very low-power factor, so that there is a great tendency to drop the voltage of the generating plant and disturb the conditions of the circuit; but this tendency is reduced to a minimum by putting in a suitable compensator. With such a compensator, although the motor may be taking perhaps three or four times full-load

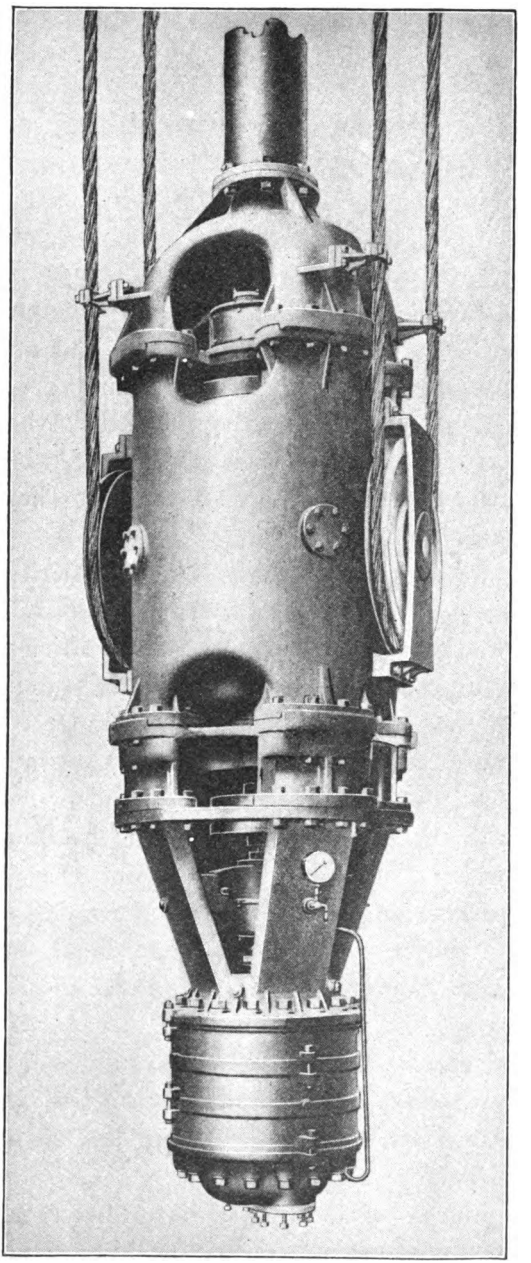


FIG. 121.—Electrically driven Centrifugal Pump capable of delivering 1000 gallons per minute against a head of 600 feet.

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current, it will be supplied at a reduced voltage by means of the transformer action of the compensator, and the actual demand from the generating plant will only be about $1\frac{1}{2}$ to 3 times full-load current of the motor.

The voltage in the case of the Dover pumps was 2000, the reason for this high voltage being that the motors were of exceptionally large size, and at 500 volts the sinking cables would have been very unwieldy and difficult to handle, as they would have been four times as large. A lower voltage is preferable, and for smaller motors, say 500 or 600 volts at the terminals, should be adopted.

With regard to the heads and quantities of water which these pumps can deal with, the only conditions which are suitable are very small quantities of water against high heads. When the gallons delivered per minute by the pump and the head in feet are about equal, a good design of pump is nearly always ensured, and a large quantity of water can also be delivered against a low head without sacrificing the design. Thus a pump can be designed to deliver 500 gallons per minute against 500 feet head, or a considerably larger quantity of water against the same head, but a satisfactory pump could not be supplied, to deliver only 100 gallons against 500 feet head.

Where three-phase current is supplied, the speed of the pump motor depends entirely on the cycles, which are generally fixed, so that the pump has to be designed to suit the speed of the motor.

Some pumps of this type have been running for several years, delivering against as high a head as 900 feet, and there should be no difficulty in making pumps (when delivering large quantities of water—say 1000

to 2000 gallons per minute) to deliver against even higher heads than this.

The approximate price of a centrifugal pump to deliver, say, 1000 gallons per minute against 600 feet head, complete with squirrel-cage motor 300 H.P., would be about £1000.[1]

Fig. 122 shows another of Messrs. Scott & Mountain's pumps, and represents one designed to deliver 500 gallons per minute against 100 feet head, driven by a squirrel-cage, three-phase, slip-ring motor, of 50 cycles, 1440 revolutions, 500 volts. The motor is started and stopped at bank by means of a compensator, and the weight of the pump, motor, rising main, and water column is all taken on the wire ropes passing round the pulleys by which the pump is slung as in the figure. This firm also make a large size of pump in which the water, instead of passing through the pipes into the "Y" piece, on which the rising main is supported, goes through a water-jacket in the motor.

Ventilation of a Sinking Pit.—The point at which it becomes necessary to resort to induced draught for the purposes of ventilating a sinking shaft will be determined by several circumstances, such as the number of the persons employed at the bottom of the shaft, the amount of blasting necessary, whether much water is falling down the shaft, and the extent to which noxious gases are generated in the strata passed through; but it is usually found that, having attained a depth of about 150 yards, if not before, the ventilation of the shaft becomes defective, and artificial means have to be resorted to.

A simple way of inducing ventilation is by means of air-boxes, 1 foot square, and constructed of $\frac{3}{4}$-inch deals, the surface end being connected to a small mechanically

[1] The author is indebted to Mr. J. E. Hodgkin for many of the particulars concerning electrical centrifugal pumps.

driven fan applied to forcing air down the boxes, to the bottom end of which is attached a length of canvas tube or bag, so as to allow of the boxing being beyond risk of injury from blasting at the shaft bottom. The fan is sometimes used to exhaust the air from, instead of forcing it into, the shaft, or the upper end of the box is connected to a chimney, in order to effect the same purpose, but the first described mode of ventilation will be found to be the best.

Dividing the shaft into two unequal portions by means of wooden bratticing is found to be an effective way of inducing natural ventilation; but it is a costly operation, which in the case of circular shafts was more largely adopted the early half of the last century than it has been of late years, as formerly the practice of permanently dividing circular shafts into compartments was more common than that of recent years. The partition when the sinking was completed, though no longer of use in the interests of ventilation, remained for the purpose of holding the central guides for the cages.

There are two methods of bratticing a shaft—(*a*) by means of buntons, and (*b*) by planks.

(*a*) In the first method, stringing planks of a cross section of 7 inches by 3 inches are fixed against the sides of the shaft by means of spikes driven into holes 1 foot deep made in the side of the shaft and plugged with wood. Then every 3 feet apart buntons are placed horizontally across the shaft by being fixed into notches cut in the stringing planks, and to them are nailed vertical cleading boards of fir 1 to 2 inches thick. (*b*) By the second method, buntons are not required, the cleading being placed horizontally and slid into grooves cut in the stringing planks.

During the process of lining the shaft with walling or

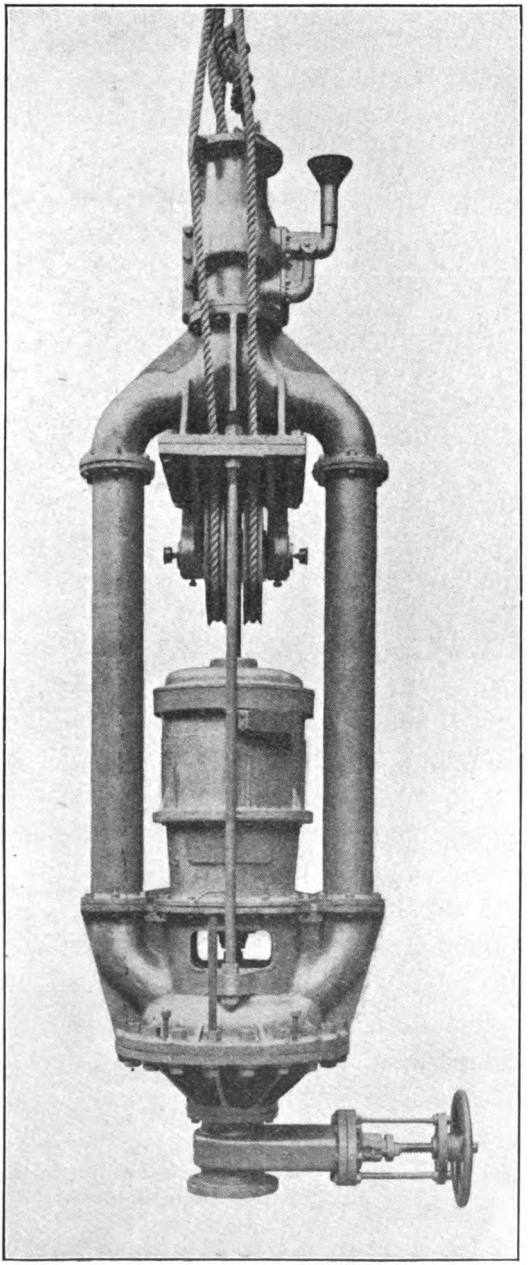


FIG. 122.—Electrically driven Centrifugal Pump.
(Messrs. Scott & Mountain.)

tubbing, it is very desirable that the space below the walling cradle should be kept properly ventilated, as otherwise explosive gases may accumulate.

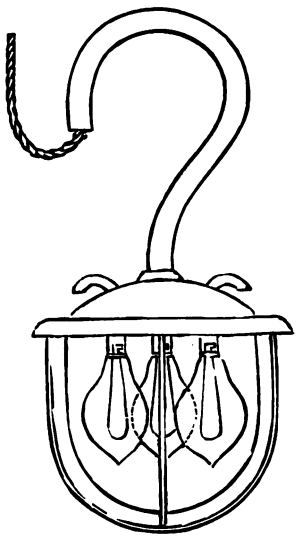


FIG. 123.—Electric Lamp Arrangement for Lighting Sinking Pits. (J. Davis & Son, Derby.)

Lighting.—Candles are very largely used for the purpose of affording light in sinking operations, but if explosive gas is generated by the strata sunk through, which is frequently the case, especially in the proximity of seams of coal or beds of carbonaceous shale, it becomes necessary to use safety lamps. One of the best means of providing illumination for the men engaged at the bottom of the shaft is, however, by means of electricity, several filament lamps being bunched together and enclosed in a strong glass globe (see Fig. 123), the light being reflected and the lamps protected from falling water by means of a metal hood, and the light raised or lowered as required by means of a cable reel (Fig. 124) situated at the surface. The drum and cheeks of the reel are built up so as to reduce the weight and liability to crack and warp, and the whole is fixed on a strong spindle mounted on a cast-iron

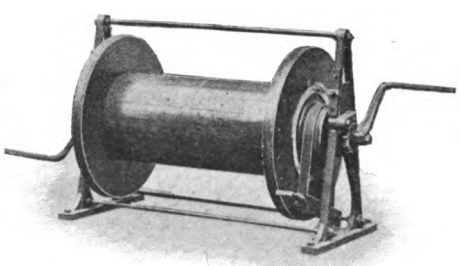


FIG. 124.—Reel for Lowering or Raising Electric Light Cable. (J. Davis & Son, Derby.)

frame; a collecting brush and ring being provided at each end of the drum, so that winding can be done without disconnecting from the main. This reel is equally applicable for conveying cable for shot-firing purposes.

CHAPTER VII

SINKING AGREEMENTS—AND COSTS OF SINKING AND LINING SHAFTS UNDER NORMAL CONDITIONS

Sinking Agreements.—It is usual in many old-established coal-mining districts to let the sinking of pits to contractors, who undertake to put down the shaft to the specified depth, and line the same at an agreed-upon price per fathom. Sometimes—indeed, usually—separate prices per fathom for the sinking and the lining are quoted, and generally the colliery company agree to drain the shaft if the influx of water exceeds a certain maximum quantity, especially if the shaft is an additional one being sunk on a property already being worked; or if the contractors agree to extract the water, then very often, but not always, a clause is inserted to the effect that if the feeders exceed a certain maximum, the contract is to be broken and prices are rearranged. Sometimes, also, there is a clause to the effect that the occurrence of an unusually thick bed (panel) of hard stone (whin[1]), the thickness being stated, "breaks the bargain."

The contractors may be miners employed on the company's works, who, being men of no capital, would not be able to undertake any great risks. The forms of specification and agreement which would be adopted in such a case are given below, and represent those used

[1] "Whin" is a term applied to basalt, but in the north of England is also extended to a very hard compact sandstone which is equal in hardness to a quartzite.

in an actual instance in the north of England not many years ago. The shaft was one sunk down to some existing underground workings, so that the drainage could be, and was, easily effected by means of a bore-hole. The strata sunk through were such as would be encountered under normal conditions. There was also little water, no loose strata, such as clays, sands, and gravel, other than the few feet of surface deposit, and there was no bed of unusually hard rock. Before quoting a price, the contractors were provided with the section of the strata passed through at a neighbouring pit about a mile distant.

Specification and Description of a Shallow Circular Shaft finished 13 feet in diameter to be sunk in the Newcastle Coalfield

SPECIFICATION and DESCRIPTION of a Pit to be sunk from the surface to the —— Seam at —— Colliery :—

1. The shaft to be 13 feet in diameter when finished. The Contractor to lay the pit out for walling whenever the nature of the stone requires it, also to set any timber that may be necessary for safety, and to put in temporary water-boxes without any extra payment for the same.

2. The Contractor to find sinkers, waiters-on, gunpowder, candles, paper, oakum, flannels for sinkers and other small stores required. The Company will find the gear and sharpen the same, but the Contractor to return it to the Company on the completion of his contract in as good condition as he received it, or pay for the deterioration or deficiency.

3. The Company will provide and erect an engine for sinking the pit and will pay for working it.

4. Contractor to prepare beds for walling, lay all cribs, put in walling, fix permanent water-boxes, temporary brattice, and do everything necessary for the completion of the work; and in tendering he is to name a price per fathom for the sinking from the surface to the stone-head, and from the stone-head to the —— Seam, for walling, water-boxes, and temporary brattice (each separately), and a lump sum for fixing each crib and the preparation of its bed.

5. The shaft to be sunk and worked by not less than six men in the bottom at any one time. The sinking to be carried on continuously from one o'clock on Monday until eleven o'clock on Saturday night in each and every week till finished.

6. Should water be met with in the course of sinking to an extent likely to impede the progress of the work, then and in that case the Company will bore a hole or drive a drift for the purpose of carrying it off.

7. In case the sinking is stopped by any obstruction, the Company will employ the sinkers at such work as they have at —— Colliery, and pay them the current rate of the day. The sinkers to be four hours out of the bottom before any payment is made for outshifts.

8. Payment to the Contractor to be made once a fortnight on the usual and accustomed pay-day within ten per cent. of the value of the work done, such percentage to be retained by the Company as a guarantee for the completion of the work, and to be paid to the said Contractor when the said work is duly finished and certified.

9. The Company's Colliery Manager for the time being, or the person he may appoint, to be the sole judge of the quality of the work and the manner in which it is conducted; and if at any time the Contractor, after six days' notice, shall refuse or neglect to alter or amend any work to which the said Colliery Manager or person appointed by him shall object, the Company shall have the power to determine the Contract, and in that case the sum of ten per cent. retained in hand by the said Company shall be forfeited.

No extras to be paid for except when ordered in writing by the Viewer.

Sealed tenders will be received up to ——.

The Company do not bind themselves to accept the lowest or any tender.

An account of the strata sunk through in the neighbouring pit may be seen at the Colliery Office by persons desirous of tendering.

Agreement made with the Contractors in respect of the Shaft alluded to in the preceding Specification.

AN AGREEMENT made the —— day of —— One thousand eight hundred and —— between —— of ——, in the county of ——, Mining Engineer, on behalf of himself and his co-partners carrying on business as coal owners in co-partnership under the firm of the —— Company, hereinafter for brevity termed the said —— Company, of the one part, and ——, in the county of —— aforesaid, hereinafter styled the said Contractors, of the other part.

1. The said Contractors agree to sink a pit from the surface to the —— Seam 13 feet in diameter when

finished and lay the same out for walling whenever the nature of the stone requires it, also to make crib beds, lay cribs, cut rings, and do all other work necessary to the completion of the pit, according to the schedule of prices appended hereto, and also to set any timber requisite for their own safety and to put in temporary water-boxes without any extra payment for the same.

2. The said —— Company agree to allow the said Contractors the use of two workmen's cottages during the progress of the work, and also to pay the said Contractors at the following rates, viz. :—

For sinking from the surface to the stone-head, eight pounds per fathom.

From the stone-head to the —— Seam, eleven pounds ten shillings per fathom.

Walling, two pounds per fathom ; temporary brattice, fifteen shillings per fathom ; permanent water-boxes, two shillings per fathom ; preparing crib bed and fixing crib, eight pounds per crib.

3. The said Contractors to find sinkers, waiters-on, gunpowder, candles, paper, oakum, flannels for sinkers, and other small stores required. The —— Company will find the gear and sharpen the same, but the said Contractors to return it to the Company at the completion of their contract in as good condition as they received it, or pay for the deterioration or deficiency.

4. The —— Company will provide and erect an engine for sinking the pit, and will pay for working it.

5. The shaft to be sunk and worked by not less than six men at any one time. The sinking to be carried on continuously from one o'clock on Monday morning until eleven o'clock on Saturday night, in each and every week till finished.

6. Should the quantity of water met with in the course

of sinking exceed 1000 gallons of water per hour, then and in that case, the —— Company will bore a hole or drive a shaft for the purpose of carrying it off.

7. In case the sinking is stopped by any obstruction, the —— Company will employ the sinkers at such work as they have at ——, and pay them the current rate of the day. The sinkers to be four hours out of the bottom before any payment is made for outshifts.

8. The said Contractors shall receive payment once a fortnight on the usual and accustomed pay-day within ten per cent. of the value of the work done, such percentage to be retained by the Company as a guarantee for the completion of the work, and to be paid to the said Contractors when the said contract is duly finished and certified.

9. The Company's Mining Engineer for the time being, or the person he may appoint, to be the sole judge of the quality of the work and the manner in which it is conducted; and if at any time the said Contractors, after six days' notice, shall refuse or neglect to alter or amend any work to which the said Mining Engineer or person appointed by him shall object, the —— Company shall have power to determine the contract, and in that case the sum of ten per cent. retained in hand by the said —— Company shall be forfeited.

No extras to be paid for except when ordered in writing by the Company's Mining Engineer.

In witness whereof the said parties hereto have hereunto set their hands the day and year first above written.

Signed by the said ——

The following is the form of agreement adopted

in the case of an 18 feet (finished) diameter shaft sunk in the Yorkshire coalfield to the depth of 500 yards. The names of the colliery and seams are purposely omitted; the seam indicated by the letter A being 154 yards from the surface; the seam indicated by the letter B being 400 yards from the surface; the seam indicated by the letter C being 500 yards from the surface. It will be observed that the undertaking was a much more extensive one than contemplated in the preceding agreement, and would be carried out in all probability by outside contractors and professional men of some capital and employing their own workmen.

AGREEMENT between —— by their agent ——, hereinafter referred to as the "Company," of the one part, and ——, hereinafter called the Contractors, of the other part, whereby the Contractors contract and agree with the Company to sink a certain new pit or shaft at the —— Colliery to the head or seam of coal known by the name of the A bed or seam at the price of —— per lineal yard until the bed of coal known as the B bed is reached by the said new pit or shaft, and therefrom at the price of —— per lineal yard until the said C bed is reached, upon the terms and conditions following:—

1. The said new pit or shaft shall be an exact circle, and so that it shall be of the diameter of 18 feet clear, measuring in any direction inside the brickwork.

2. The said new pit or shaft shall be walled or lined by the Contractors with nine-inch brickwork, composed of bricks to be provided by the Company.

3. The said new pit or shaft shall be sunk with the greatest quickness and despatch consistent with safety, and the workmen sinking the same shall work

in three shifts of eight hours each, with at least ten men in each shift.

4. The new pit or shaft shall be sunk in a good and workmanlike manner and in the most approved method now in use for sinking pits or shafts of a similar size.

5. The Company shall find and provide all engine-power necessary for the sinking of the said new pit or shaft, and the Contractors shall find and provide the necessary banksmen to remove and tip the earth and store the refuse and spoil raised during the sinking of the said shaft a distance of twenty yards from the said shaft, or within such distance into wagons to be provided by the Company at their option; and when so tipped at such distance or into such wagons, the Company shall then remove or deal with the same as they think fit. And the said Company shall also find and provide all necessary working machinery and pumping machinery during the sinking of the said new pit or shaft and all labour necessary for putting in and working the same, and shall also provide and keep in repair all tools, implements, and safety lamps necessary for such sinking, and shall also provide all brick, stone, mortar, lime, coal, and other materials necessary for the sinking and finishing of the said new pit or shaft, except the articles and things hereinafter agreed to be provided by the Contractors.

6. The said Contractors shall, however, by themselves or their workmen, lade out of the said shaft during the sinking thereof, if necessary, so much of such water as may find its way therein as shall in the judgment of ——, the certified Manager at the said —— Colliery, or the certified Manager of such Colliery for the time being, be a reasonable quantity of water to be laded out without the use of pumping machinery, not exceeding,

however, an average of two hundred gallons per hour per day.

7. The said Contractors shall find and provide all powder and fuse for blasting and all necessary working clothes for sinkers, and shall also find and provide all necessary labour and men other than those herein agreed to be found by the Company; and the Contractors shall not allow any explosive substance except gunpowder to be used in or about the said new pit or shaft unless by the written permission of the said certified Manager.

8. The sinking of the said new pit or shaft, and all work therein, shall be done and performed by the said Contractors to the satisfaction of the said ——, the certified Manager, and in such way or manner for ensuring safety, and in other respects, as he may from time to time direct; no money shall be due or payable to the said Contractors from the Company in respect of the sinking of the said new shaft, or for or on account of any work done or performed in or about the same, unless such sinking and work shall have been done and performed to the entire satisfaction of the said ——, the certified Manager.

9. Weekly[1] payments shall be made on every Saturday in part payment for and on account of work done by the said Contractor during the week ending the then previous Thursday, but such payments shall not be taken or considered as expressing the satisfaction of the said ——, the certified Manager, in respect of the sinking or work done in the then previous or any preceding week to such payments.

[1] It is the custom to pay miners weekly in Yorkshire and most other mining districts in Great Britain; but in Northumberland and Durham miners' wages are paid fortnightly.

10. A "certain" percentage of the moneys which may from week to week be payable to the said Contractors for work done in the sinking of the said shaft, shall be retained in hand by the Company until the said new shaft and all work agreed to be done by the said Contractors under this Agreement shall be completed and finished to the satisfaction of the said ——, the certified Manager; but when such new pit or shaft and work are so completed and finished as aforesaid, then all moneys due or payable to the said Contractors under this Agreement shall be paid over to them by the Company.

11. When the said new shaft shall have reached the seam of coal known as the "C" seam, the said ——, the certified Manager, shall have power, if he think fit, by a notice in writing, to stop the further sinking of the said shaft.

12. The Contractors shall in all respects themselves observe, perform, and cause their workmen to observe and perform during the sinking of the said shaft all the provisions and regulations of the Coal Mines Regulation Acts,[1] and hereby agree to indemnify the Company,[2] or their certified Manager, against any penalty or damage they may suffer or be put to in consequence of any non-observance or non-performance by the said Contractors or their workmen, or by any servants of the Company who, although their wages may be paid by the Company, shall for the time being be under the direction or control of the Contractors, of any such provisions and regulations.

13. In case the Contractors shall not proceed with

[1] This Agreement was drawn up prior to the Explosives in Coal Mines Order and the Workmen's Compensation Acts.

[2] *Ibid.*

the sinking of the said shaft with due diligence and speed to the satisfaction of the said ——, the certified Manager, or in case the Contractors shall not execute and do the work by them under this Agreement contracted to be performed and done to the satisfaction of the said ——, the certified Manager aforesaid, or in case the Contractors shall in any other respect fail or neglect to observe and perform the conditions and provisions herein contained, then the said ——, the certified Manager as aforesaid, may, by notice in writing under his hand, determine the contract, and thereupon the same shall be at an end; and in case by such determination or ending of the contract the Company shall sustain or be put to loss or damage, then the Contractors shall forthwith pay and make good to the Company any such loss or damage.

As witness the hands of the said parties to these presents the —— day of —— One thousand, &c.

In neither of the cases instanced above was the tubbing back of water necessary. Were such necessary, it would indicate a more difficult sinking, and if not undertaken by some substantial and experienced expert contractor, would in all probability have to be carried out by the Company itself—at any rate when passing through the water-bearing strata—paying a definite wage to the sinkers, as it would hardly allow of its being let by contract.

Costs.—The cost of sinking and lining shafts, even when they are put down under normal conditions in respect of hardness of strata and influx of water, vary greatly. The rate of wages at the time the work is being performed, governed as this is by such varying factors as the country in which the operation is being

carried out, as well as price of the materials used in the work, and the distance the same has to be transported, enters so largely into this consideration that it is impossible to lay down any even approximate rule for general application in this respect. The author has found, however, in such sinkings in the United Kingdom with which he has had practical experience, that a rough and ready rule for calculating the cost of labour alone for sinking a shaft when no particular difficulties are encountered in respect to influx of water, hardness of strata, or where no loose beds have to be sunk through, is to allow one pound per foot diameter (finished) of shaft per fathom sunk.

Mr. J. H. Merivale, a well-known authority on mining in the north of England, has given the following useful items of cost in connection with the sinking and equipping of a 14 feet diameter shaft sunk to 100 fathoms,[1] viz. :—

Total labour cost of sinking and walling	£25	0	0	per fathom.	
Contractor for sinking, including small stores	14	0	0	,,	,,
Making walling beds	6	0	0	each.	
Walling with fire-clay lumps	15	0	0	per fathom walled.	
Tubbing with cast-iron segments	90	0	0	,,	,, tubbed.
Plank brattice	2	10	0	,,	,,
Guides of wood	0	15	0	,,	,,
Iron or steel rail guides, 50 lbs. per yard	2	10	0	,,	,,
Wire rope guide	1	5	0	,,	,,
Total cost for the finished pit	50	0	0	,,	,,

The following actual instances that came before the notice of the author are useful exemplifications :—

Cost of Walling a Shaft with Fire-clay Lumps.—

[1] *Notes and Formulæ for Mining Students*, by J. H. Merivale, M.A., third edition, p. 76.

Walling with fire-clay lumps 9 inches on the bed. Diameter of shaft (*i.e.* when finished) = 10 feet 3 inches.

32 lumps per course and 18 courses per fathom—weight, 8½ tons, at 20s. per ton	£8	10	0
Lime	0	3	0
Mason work	1	0	0
Sending material, &c., down	1	0	0
Total cost per fathom	£10	13	0
If built with cement, £1, 17s. extra, or per fathom	£12	10	0

Cost of Lining a Shaft with ordinary Cast-iron Tubbing.

Cost of tubbing a 15 feet diameter pit sunk 180 fathoms, Co. Durham, and lining same with fire-bricks for upcast shaft at £77, 16s. 6d. per fathom—83 fathoms	£6459	9	6
Putting in same at £6 per fathom	498	0	0
Sheathing same at £1, 13s. per fathom	136	19	0
Wedges for 83 fathoms at £1, 17s. 6d.	155	12	6
Fire-brick lining, 83 fathoms at £2, 4s. 8d.	185	7	4
Putting in do., 83 fathoms at £3 per fathom	249	0	0

The following details as to costs in respect to sinking, walling, tubbing, and equipping shafts at some collieries as to which the author has particular knowledge, are of value as a guide in making out estimates, and as illustrating the cost of the various items:—

Cost of Sinking and Equipping a 15 feet diameter Pit at —— Colliery, in the County of Durham.

Price of a circle of crib 6 inches by 5 inches = 56·5 fathoms at 10d. = £2, 7s. 1d., and price per fathom, 3 cribs being in one fathom = £7, 1s. 3d.

Laying down do., including cleats and nails, 5s. per circle = 15s. per fathom.

Backing deals, 425 superficial feet per fathom at 10s. per 100 feet = £2, 2s. 6d. per fathom.

Putting in timber, £5 per fathom.
Baff ends and spears, 20s. per fathom.
Plate brick walling, each brick 4 inches by 12 inches on face and 9 inches on bed, number in one fathom = 848—232 weighing 29 lbs. each = 11 tons per fathom at 13s. 8d. per ton = £7, 10s. 4d. per fathom.
Putting in all walling at £4 per fathom.
Walling cribs at £3, 10s. per crib.
Tubbing, 36 segments, 3 feet 10½ inches by 2 feet, in a fathom, each segment weighing 7⅞ cwts.—283 cwts. per fathom at 5s. 6d. per cwt. = £77, 16s. 6d. per fathom.
Putting in tubbing, £6 per fathom.
Sheeting, 33s. per fathom.
Wedges, 3000 at 1s. 3d. = £1, 17s. 6d. per fathom.
Fire-brick lining for tubbing, each brick 12 inches by 9 inches on face by 3 inches on bed—number in one fathom, 337, weighing 21¾ lbs. each = 3 tons 5 cwts. 1 qr. 22 lbs. per fathom at 13s. 8d. per ton = £2, 4s. 8d. per fathom.
Putting in fire-brick lining, £3 per fathom.
Brattice, 49s. 6d. per fathom.
Putting in do., 8s. 6d. per fathom.
Water-boxes, 5s. per fathom.
Cutting rings for conveying water into boxes, £4 each.
Sinking pit, £18 per fathom.
Wedging cribs, £24 each.
Cutting bed, laying and wedging do., £11 each.

Jack engine for sinking with pulleys and frames			£300	0 0
Winding-engine			3,000	0 0
Roofing for do.			160	0 0
Pulley framing, 316 feet at 30s.	£474			
Pulleys	100			
Erecting	50			
		——	624	0 0
Six screens at £75 each	£450			
Framing, flooring, roof, &c., £80 each	480			
		——	930	0 0
300 tubs at £3, 10s. each			1,050	0 0
6 boilers, with all connections, at £140 each			840	0 0
6 patent furnaces at £100			600	0 0
Roofing for six boilers			225	0 0
Engine pillars, 15,456 feet at 1s. 3d.			966	0 0
Carried forward			£8,695	0 0

Brought forward . .	£8,695	0	0
Pumping apparatus	650	0	0
Pumping pillars, 3840 feet at 1s. 3d.	240	0	0
Guides, buntons, and keeps	1,100	0	0
1 plain crab with shear legs	120	0	0
Main crab rope	130	0	0
Crab drifts, 70 yards at 30s. per yard	105	0	0
2 ground crabs at £28 each	56	0	0
2 ground crab ropes at £56	130	0	0
Ground blocks and sheaves	60	0	0
Sinking gear	200	0	0
Sinking 6 feet staple, £5 per fathom. Cribs 4½ by 5 inches, 25 feet per circle, at 10d. = 20s. each.			
Laying down do., including cleats and nails, 2s. 3d. each.			
Backing deals, 187½ feet per fathom at 10s. per 100 feet = 19s. 3d. per fathom.			
Stone walling, £3, 6s. per fathom.			
Putting in do., £2, 5s. per fathom.			
Settings for 6 boilers at £60 each	360	0	0
Labour for do.	72	0	0
	£11,918	0	0

Ground spears for sinking set, 8 inches by 7 inches, 150 fathoms (2⅓ cubic feet in 1 fathom) = 350 cubic feet at 3s. 6d.	£61	5	0
Pumping spears, 8 inches by 7 inches = 112½ fathoms (2⅓ cubic feet in 1 fathom) = 262½ cubic feet at 3s. 6d.	45	18	9
10 pairs ground spear clambs, 8 cwts. 0 qr. 4 lbs. at 14s.	5	12	6
Bolts for do., 1 cwt. 1 qr. 20 lbs. at 22s. . . .	1	11	5
40 19-inch common pumps, 24 cwts. each = 960 cwts. at 6s.	228	0	0
2 clack pieces and 2 wind-bores, 101 cwts. at 8s 6d. .	42	18	6
2 bucket trees, 123 cwts. at 8s. 6d.	52	5	6
2 18-inch working barrels, 72 cwts. at 9s. . . .	32	8	0
48 joint rings at 10s. each	24	0	0
Bolts for 48 joints, 8 bolts in each joint = 384 bolts, each weighing 7 lbs. = 24 cwts. at 21s. . . .	25	4	0
40 pairs spear plates (1 weighing one-third of a ton) = 13½ tons at £21	280	0	0
14 bolts in each joint in 40 joints = 560 at 6½ lbs. = 1⅝ tons at £22	35	15	0
Carried forward . . .	£834	18	8

Brought forward . .	£834	18	8
8 U plates, 48 cwts. 0 qr. 20 lbs., at £24 . . .	57	16	3
4 bucket joints complete (1 weighing 1 cwt. 2 qrs. 4 lbs. = 6 cwts. 1 qr. 10 lbs.), at 50s.	17	4	0
6 bucket hoops (1 weighing 1 qr. 18 lbs. = 2 cwts. 1 qr. 24 lbs.), at 1s. per lb.	13	16	0
4 brass bucket shelves and 4 do. clack shells (each weighing 1 cwt. 0 qr. 24 lbs. = 9 cwts. 2 qrs. 24 lbs.), at 1s. 4d. per lb.	72	10	8
Standing set buntons, 50 fathoms at £5, 10s. . .	275	0	0
Iron for 6 bottom-rods (each weighing 3 cwts. 3 qrs. 12 lbs. = 23 cwts. 0 qr. 16 lbs.), at 12s. . . .	13	17	8
24 bucket door bolts (each weighing 1 qr. 2 lbs. = 6 cwts. 1 qr. 20 lbs.), at 18s.	5	15	8
	£1,290	18	11
24 cross bars (each weighing 2 qrs. 24 lbs. = 17 cwts. 0 qr. 16 lbs.), at 32s.	£27	8	6
4 clack rods, keeps, cross bars, and falls, smithed and finished, 4 cwts. 0 qr. 4 lbs., at 49s. . . .	9	17	9
Fitting to above	4	8	0
2 pairs of hanging straps, with bolts and keeps, smithed and planed, 12 cwts. 0 qr. 10 lbs., at 35s. . .	21	3	2
2 brasses for same, 88½ lbs., at 1s. 4d.	4	15	10
	£67	13	3
Sinking a pit 180 fathoms at £18 per fathom . .	£3,240	0	0
Cribs, 50 fathoms at £7, 1s. 3d. per fathom . .	353	2	6
Laying down do., 50 fathoms at 15s. per fathom .	37	10	0
Backing deals, 50 fathoms at £2, 1s. 6d. . . .	106	5	0
Baff ends and spans, 50 fathoms at 20s. . . .	50	0	0
Plate brick walling, 87 fathoms at £7, 10s. 4d. .	653	19	0
Putting in walling, 87 fathoms at £4 per fathom .	348	0	0
10 walling cribs at £3, 10s. per crib	35	0	0
Tubbing 83 fathoms at £77, 16s. 6d. per fathom .	6,459	9	6
Putting in tubbing, 83 fathoms at £6 per fathom .	498	0	0
Sheeting, 83 fathoms at 33s. per fathom . . .	136	19	0
Wedges, 83 fathoms at £1, 17s. 6d. per fathom .	155	12	6
Fire-brick lining, 83 fathoms at £2, 4s. 8d. per fathom	185	7	4
Putting in do., 83 fathoms at £3 per fathom . .	249	0	0
Carried forward . .	£12,508	4	10

Brought forward . .	£12,508	4	10
Permanent brattice, 180 fathoms at £2, 9s. 6d. .	445	10	0
Putting in do., 180 fathoms at 8s. 6d. per fathom .	76	10	0
Water-boxes, 145 fathoms at £5 per fathom . .	36	5	0
Cutting 6 rings for conveying water in boxes, at £4 .	24	0	0
20 wedging cribs at £24 each	480	0	0
Cutting bed, laying, and wedging, at £11 each . .	220	0	0

STAPLE

Sinking staple, 35 fathoms at £5, 10s. per fathom .	£175	0	0
Cribs, 15 fathoms at £3, 2s. 6d. per fathom . .	46	17	6
Laying down do., 15 fathoms at 6s. 9d. per fathom .	5	1	3
Backing deals, 15 fathoms at 19s. 3d. per fathom .	14	8	9
Putting in do., 15 fathoms at 30s. per fathom . .	22	10	0
Stone walling, 35 fathoms at £3, 6s. . . .	115	10	0
Putting in do., 35 fathoms at £2, 5s. . . .	78	15	0
	£14,248	12	4
To sinking through the sand	1,000	0	0
Amounts brought forward	11,918	0	0
„ „ „	1,290	18	11
„ „ „	67	13	3
	£28,525	4	6
Chimney	120	0	0
	£28,645	4	6
Less plant realisable on completion of the undertaking	1,500	0	0
	£27,145	4	6

Cost per Fathom of Sinking and Equipping a 12 feet Pit at —— Colliery, in the County of Durham.

Price of a circle of cribs, 6 inches by 5 inches = 47·12 feet at 10d.	£1	19	3
Price per fathom containing 3 cribs	5	17	9
Laying down do., including cleats and nails, 5s. 6d. per circle, cost per fathom	0	15	0
Backing deals, 350 feet per fathom, at 10s. per 100 feet.	1	15	0

	£	s.	d.
Putting in all timber, per fathom	£5	0	0
Baff ends and spars	0	16	0
Plate brick walling, each brick 12 inches by 4 inches on face and 9 inches on bed, number per fathom 678·6, each weighing 29 lbs. = tons 8·75, at 13s. 8d. per ton	5	19	7
Putting in all walling	3	5	0
Walling cribs, per crib	3	10	0
Tubbing, 40 segments, each 6 cwts. 1 qr. 4 lbs., 3 feet 9 inches by 18 inches, 255 cwts. per fathom, at 5s. per cwt., cost per fathom	63	15	0
Putting in tubbing, cost per fathom	5	0	0
Sheeting, cost per fathom	1	13	0
Wedging, 3000 at 1s. 3d., cost per fathom	1	17	6
Fire-brick lining for tubbing, each brick 12 inches by 9 inches on face by 3 inches on bed, number per fathom 252, weighing 21¾ lbs. each = 2 tons 9 cwts. per fathom, at 13s. 8d. per ton, cost per fathom	1	13	6
Putting in fire-brick lining, cost per fathom	2	0	0
Main brattice	1	19	0
Putting in do., cost per fathom	0	6	9
Water-boxes, cost per fathom	0	5	0
Cutting rings for conveying water in boxes, each	4	0	0
Sinking pit, cost per fathom	15	0	0
Wedging cribs, each	19	0	0
Cutting bed, laying and wedging do.	8	16	0
Sinking gear	200	0	0
Sinking 6 feet staple at £5 per fathom	5	0	0
Cribs, 4½ inches by 5 inches, 25 feet per circle at 10d., cost per circle	1	0	10
Cost of do. per fathom	3	2	6
Laying down do., including cleats and nails, per circle	0	2	3
Backing deals, 187½ feet per fathom at 10s. per 100 feet, per fathom	0	19	3
Putting in backing deals, 187½ feet per fathom at 10s. per 100 feet, per fathom	1	10	0
Stone walling, 187¼ feet per fathom at 10s. per 100 feet, per fathom	3	6	0
Putting in stone walling, 187½ feet per fathom at 10s. per 100 feet, per fathom	2	5	0

Cost of Sinking and Equipping two 12 *feet diameter Pits to a depth of* 180 *fathoms.*

1. Surface Erections, Winding, Pumping, and Sinking Engines, Headgear, Boilers, and Screens.

Two engines for sinking pit, with pulleys and pulley frames, complete				£600	0	0
2 winding engines				5,000	0	0
Roofing for do.				320	0	0
Pulley framing, 632 feet at 30s.	£948	0	0			
Pulleys	200	0	0			
Erecting	100	0	0			
				1,248	0	0
6 screens at £75 each	£450	0	0			
Framing, flooring, roofs, &c., £80 each	480	0	0			
				930	0	0
9 boilers, with all connections, at £140 each				1,260	0	0
9 patent furnaces at £100				900	0	0
Roofing for 9 boilers				337	10	0
Chimney				170	0	0
Engine pillars, 30,912 feet at 1s. 3d.				1,932	0	0
Pumping apparatus				650	0	0
Pumping pillars, 3840 at 1s. 3d.				240	0	0
Guides, buntons, and keps				2,240	0	0
One main crab with shear legs				120	0	0
Main crab rope				130	0	0
Crab drifts, 70 yards at 30s. per yard				105	0	0
2 ground crabs at £28				56	0	0
2 ground crab ropes at £65				130	0	0
Ground blocks and sheaves				60	0	0
Settings for 9 boilers at £60				540	0	0
Labour for do.				108	0	0
600 tubs at £3, 10s. each				2,100	0	0
				£19,176	10	0

2. Pumping Arrangements in Shaft.

	£	s.	d.
Ground spears for sinking set, 8 feet by 7 feet, 150 fathoms ($2\frac{1}{3}$ cubic feet per fathom) = 350 cubic feet at 3s. 6d.	£61	5	0
Pumping spears, 8 inches by 7 inches, $112\frac{1}{2}$ fathoms ($2\frac{1}{3}$ cubic feet per fathom) = $202\frac{1}{2}$ cubic feet at 3s. 6d.	45	18	9
10 pairs ground clambs, 8 cwts. 0 qr. 4 lbs. at 14s.	5	12	6
Bolts for do., 1 cwt. 1 qr. 20 lbs. at 22s.	1	11	5
40 19-inch common pumps, 24 cwts. each = 960 cwts. at 6s.	288	0	0
2 clack pieces and 2 wind-bores, 101 cwts. at 8s 6d.	42	18	6
2 bucket trees, 123 cwts. at 8s. 6d.	52	5	6
2 18-inch working barrels, 72 cwts. at 9s.	32	8	0
48 joint rings at 10s. each	24	0	0
Bolts for 48 joints, 8 bolts per joint, 384 bolts, each 7 lbs. = 24 cwts. at 21s.	25	4	0
40 pairs spear plates (1 weighing one-third of a ton) = $13\frac{1}{3}$ tons at £21	280	0	0
14 bolts in each joint in 40 joints, 560 at $6\frac{1}{2}$ lbs. each = $1\frac{5}{8}$ tons at £22 per ton	35	15	0
8 N. plates, 48 cwts. 0 qr. 20 lbs. at £24	57	16	3
Bucket joints, complete, 1 weighing 1 cwt. 2 qrs. 4 lbs. = 6 cwts. 0 qr. 16 lbs., at 56s.	17	4	0
6 Bucket hoops (1 weighing 1 qr. 18 lbs.) = 2 cwts. 1 qr. 24 lbs., at 1s. per lb.	13	16	0
4 brass bucket shells and 4 brass clack shells (each 1 cwt. 0 qr. 24 lbs.) = 9 cwts. 2 qrs. 24 lbs., at 1s. 4d. per lb.	72	10	8
Standing set buntons, 50 tons at £5, 10s.	275	0	0
Iron for 6 bottom-rods (each 3 cwts. 3 qrs. 12 lbs.) = 23 cwts. 0 qr. 16 lbs. at 12s.	13	17	8
24 bucket door bolts (each 1 qr. 21 lbs.) = 6 cwts. 1 qr. 20 lbs. at 18s.	5	15	8
24 cross bars (each 2 qrs. 24 lbs.) = 17 cwts. 0 qr. 16 lbs. at 32s.	27	8	6
4 clack swords, keeps, cross bars, and falls, smithed and finished, 4 cwts. 0 qr. 4 lbs. at 49s.	9	17	9
Fitting to above	4	8	0
2 pairs hanging straps with bolts and keeps, smithed and finished, 12 cwts. at 35s.	21	3	2
2 brasses for same, $88\frac{1}{2}$ lbs. at 1s. 1d.	4	15	10
	£1,368	9	2

3. Sinking and Lining Shaft.

Sinking pit, 180 fathoms at £15 per fathom	£2,700	0	0
Cribs, 50 fathoms at £5, 17s. 9d.	294	7	6
Laying down do., 50 fathoms at 15s. per fathom	37	10	0
Backing deals, 50 fathoms at £1, 15s.	87	10	0
Baff ends and spares, 50 fathoms at 16s.	40	0	0
Plate brick walling, 87 fathoms at £5, 19s. 7d.	520	3	9
Putting in walling, 87 fathoms at £3, 5s.	282	15	0
10 walling cribs, at £3, 10s. per crib	35	0	0
Tubbing, 83 fathoms at £63, 15s. per fathom	5,291	5	0
Sheeting, 83 fathoms at £1, 13s. per fathom	136	19	0
Wedges, 83 fathoms at £1, 17s. 6d. per fathom	155	12	6
Fire-brick lining, 83 fathoms at £1, 13s. 6d.	139	0	6
Putting in do., 83 fathoms at £2	166	0	0
Permanent brattice, 180 fathoms at £1, 19s.	351	0	0
Putting in do., 180 fathoms at 6s. 9d.	60	15	0
Water-boxes, 145 fathoms at 5s.	36	5	0
Cutting 6 rings for conveying water into boxes at £4	24	0	0
20 wedging cribs at £19 each	380	0	0
Cutting bed, laying and wedging do., £18, 16s.	176	0	0
Sinking through the sand	750	0	0
Putting in tubbing, 83 fathoms at £5 per fathom	415	0	0
Sinking staple, 35 fathoms at £5 per fathom	175	0	0
Cribs, 15 fathoms at £3, 2s. 6d. per fathom	46	17	6
Laying down do., 15 fathoms at 6s. 9d. per fathom	5	1	3
Backing deals, 15 fathoms at 19s. 3d. per fathom	14	8	9
Stone walling, 35 fathoms at £3, 6s. per fathom	115	10	0
Putting in do., 35 fathoms at £2, 5s. per fathom	78	15	0
	£12,514	15	9

Cost of sinking and lining two 12 feet pits	£25,029	11	6
Amount brought forward	19,176	10	0
Do. do.	1,368	9	2
	£45,574	10	8
Less plant realisable on completion of sinking	2,750	0	0
	£42,824	10	8

Cost of Sinking and Equipping a Pit, Depth of Shaft 85 fathoms, Diameter 15 feet.

To sinking 85 fathoms at £15	£1275	0	0		
Walling with fire-bricks	400	0	0		
Brattice in shaft	250	0	0		
To Temporary timber, including deals and nails	200	0	0		
2 sets of 14-inch pumps, wind-bore, blackpiece, bucket door, and spear plates	650	0	0		
1 pair 14-feet round rope pulleys with carriages and bed-plates, complete	100	0	0		
Heapstead	1000	0	0		
1 double 30-inch cylinder engine, stroke 6 feet, with rope role, brake gear, all complete	1250	0	0		
1 donkey-engine for feeding boiler	50	0	0		
With pipes	60	0	0		
Cistern with cast-iron columns	55	10	0		
To 4 malleable iron boilers, 40 feet long by 5 feet diameter	720	0	0		
Crab-engine with steam exhaust pipes	550	0	0		
Crab sheaves with carriages, bed-plates, complete	130	0	0		
To apparatus—				£6,690	10	0
1 engine-house with boiler seats	£1500	0	0		
Crab-engine house	240	0	0		
Smith sharper, lamp-house	200	0	0		
Store-room and stable	330	0	0		
Pulley frames, with stays and gangway and planking joists, complete	700	0	0		
5 new screens with turning cradles	500	0	0		
8 guide ropes and weights	360	0	0		
				3,830	0	0
3 pit ropes and rapper ropes	£230	0	0		
Crab do.	40	0	0		
Buntons and frame-work keeper	190	0	0		
Flat sheets	60	0	0		
Carried forward	£520	0	0	£10,520	10	0

Brought forward . .	£520	0	0	£10,520	10	0
4 cages complete, with chains . .	200	0	0			
Joiner's and blacksmith's shop . .	500	0	0			
40 cottages, complete, at £90 . .	3600	0	0			
100 tons of rails at 6s. 10d. . . .	650	0	0			
Cast-iron tramway turns . . .	200	0	0			
300 coal steel tubs at 90s. . . .	1350	0	0			
Workmen's gear	50	0	0			
6 horses at £50 each	300	0	0			
6 carts at £12 each	72	0	0			
2 long do. at £14 each . . .	28	0	0			
1 road waggon at £24	24	0	0			
Harness	15	0	0			
12 pit ponies at £12 each . . .	144	0	0			
4 pit horses at £30 each . . .	120	0	0			
10 sets of liners and harness . .	10	0	0			
6 horses' keep and driver . . .	624	0	0			
				8,407	0	0
To 200 coke ovens and rails at £35	£7000	0	0			
20 coal tubs at 150s.	150	0	0			
1000 yards of 4-inch water-pipes at 5s. .	250	0	0			
200 yards of 7-inch water-pipes at 10s.	100	0	0			
100 yards of water-valves at 20s. .	100	0	0			
Gear crook bolts	150	0	0			
				7,750	0	0
To 2000 tons of coals at 2s. 6d. per ton, for workmen, and engines during time of sinking	£250	0	0			
Cutting foundation	300	0	0			
Extra leading and carting . . .	100	0	0			
				650	0	0
Total cost				£27,327	10	0

Estimated Cost of Sinking a 16 *feet Finished Pit, depth* 150 *fathoms.*

To sinking a pit 150 fathoms at £25 per fathom	£3,750	0	0
Cribs, 30 fathoms at £7 . . .	210	0	0
Carried forward . .	£3,960	0	0

Brought forward . .	£3,960	0	0	
Laying down, backing deals, baff ends, and spars, 30 fathoms at £5 . .	150	0	0	
Walling with fire-clay lumps, 90 fathoms at £13	1,170	0	0	
10 walling cribs at £7 . . .	70	0	0	
Tubbing, 60 fathoms at £120 . .	7,200	0	0	
Sheeting, wedging, &c., 60 fathoms at £5	300	0	0	
Fire-brick lining, material and labour, 60 fathoms at £5	420	0	0	
Putting in tubbing, 60 fathoms at £6 .	360	0	0	
12 wedging cribs, labour and material, at £30 each	360	0	0	
Air-boxes, &c., 50 fathoms at 15s. .	37	10	0	
Building up $\frac{5}{4}$ and main coal seams around shaft, and building sound rubble wall, 3 feet thick . . .	150	0	0	
				£14,157 10 0

N.B.—This pit was sunk in the "good times," when everything was abnormally dear, and wages very high.

CHAPTER VIII

SINKING THROUGH SURFACE SANDS AND GRAVELS—PILING: WALKER'S METHOD; THE SINKING DRUM PROCESS; HAASE'S METHOD; THE HONIGMANN METHOD; THE PATTBERG BORER

SINKING through running strata, whether the beds occur at the surface or at depth and overlaid by beds of another character, constitutes one of the most difficult of the problems connected with mining. For, besides the shifting and unstable nature of the ground itself, the fact that water is nearly always present in considerable quantities renders the operation much more complex. The following are some of the methods that have been adopted in sinking and lining shafts passing through surface deposits of this nature when of abnormal thickness.

Wooden Piling.—A notable instance of the adoption of wooden piling for the purpose of penetrating surface deposits was at Framwellgate Moor Colliery, near Durham, sixty-three years ago, where a considerable depth of alluvium had to be sunk through before the stone-head was reached. The shaft was commenced at a diameter of 30 feet, and the upper clay passed through and the sides supported in the usual manner with wooden curbs, 6 inches square, and backing deals. Through the remainder of the distance, to the stone-head, piling was resorted to (see Fig. 125), and finally the stone-head reached after 120 feet had been sunk through, the diameter of the shaft being then only $14\frac{1}{3}$ feet.

It is usual, when this form of piling is adopted, to use piles of pitch pine, about 15 feet long, 6 inches wide, and 3 inches thick, the lower end being pointed and shod with iron, and the driving end protected with iron hooping. The edge of the piles should be bevelled, so as to allow of their fitting into each other.

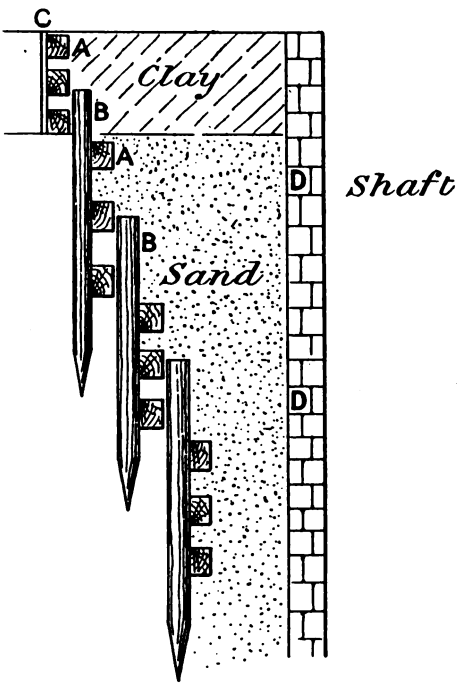


FIG. 125.—Wooden Piling through Sand. A, Cribs; B, Piles; C, Backing Deals; D, Walling.

It will be seen that the reduction in the size of the shaft, if the alluvial deposit is thick, is very considerable. Thus, supposing the depth of the deposit, as determined by a bore-hole, is 120 feet, and it is desired that the diameter of the shaft shall, when finished, be about 16 feet, it will be necessary to commence the sinking at a diameter of 31 feet, as the following calculation shows:—

With 15-feet piles it will be necessary to commence a fresh course every 12 feet.

$$120 \text{ feet} \div 12 = 10 \text{ feet},$$

and the piles being 3 inches thick and the curbs or cribs 6 inches, the reduction in the diameter of the shaft with each course will be (3 inches + 6 inches) 2 = 1 foot 6 inches, and 1 foot 6 inches × 10 = 15 feet, and 16 + 15 = 31 feet.

Another well-known instance of the use of piling is

that described by Mr. A. L. Steavenson[1] in his account of the Bowburn Winning, in the neighbourhood of the city of Durham, when before the stone-head could be reached, 156 feet 9 inches of sand, gravel, and clay had to be passed through. The shaft was started at 25 feet diameter, in order that it might finish at 13 feet, but so successfully were the piling operations carried out that it finished at 15 feet. The shaft was sunk by ordinary methods to a depth of 89 feet 3 inches, chiefly through stoney clay, but after this it was found necessary to commence piling. Fig. 126[2] illustrates the manner in which this was effected. The cribs (*a*) were 6 inches square and placed 21 inches apart, supported by punch props (*d*) 4 inches in diameter. The backing deals (*b*) were $1\frac{1}{4}$ inch thick and 7 inches wide. The lowest crib was inserted at a depth of 101 feet, and the lower portion lined with grooved and tongued deals (*e*). Then a crib (*f*) was suspended by chains, a space of $2\frac{1}{2}$ inches being left for the insertion of the piles, and below this again a similar crib (*g*) was laid, the segments being fastened together by iron plates 3 feet long by 3 inches wide by $\frac{1}{2}$ inch thick, bolted with six through bolts and going down with the piling. *h* represents the pitch-pine piles, 7 inches by $2\frac{1}{2}$ inches thick and 15 feet in length, which were scarfed for a length of 6 inches and blackleaded to give easiness of travel. Three men worked the wooden ram used for driving down the piles, one at the lower end and two at the top; and during the driving down process the sand at the bottom was removed so as to allow of the descent of the sinking crib.

When the piles were driven down, the cribs were

[1] "Bowburn Winning," by A. L. Steavenson, *Trans. Inst. M.E.*, vol. xxxii. p. 385.

[2] The author is permitted to reproduce this illustration through the kindness of the Council of the Institution of Mining Engineers.

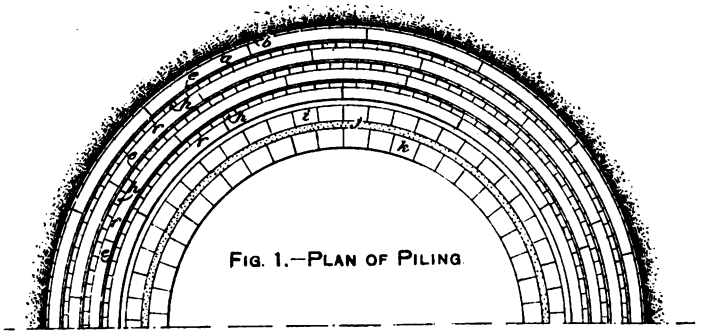


FIG. 1.—PLAN OF PILING.

FIG. 2.—VERTICAL SECTION OF PILING.

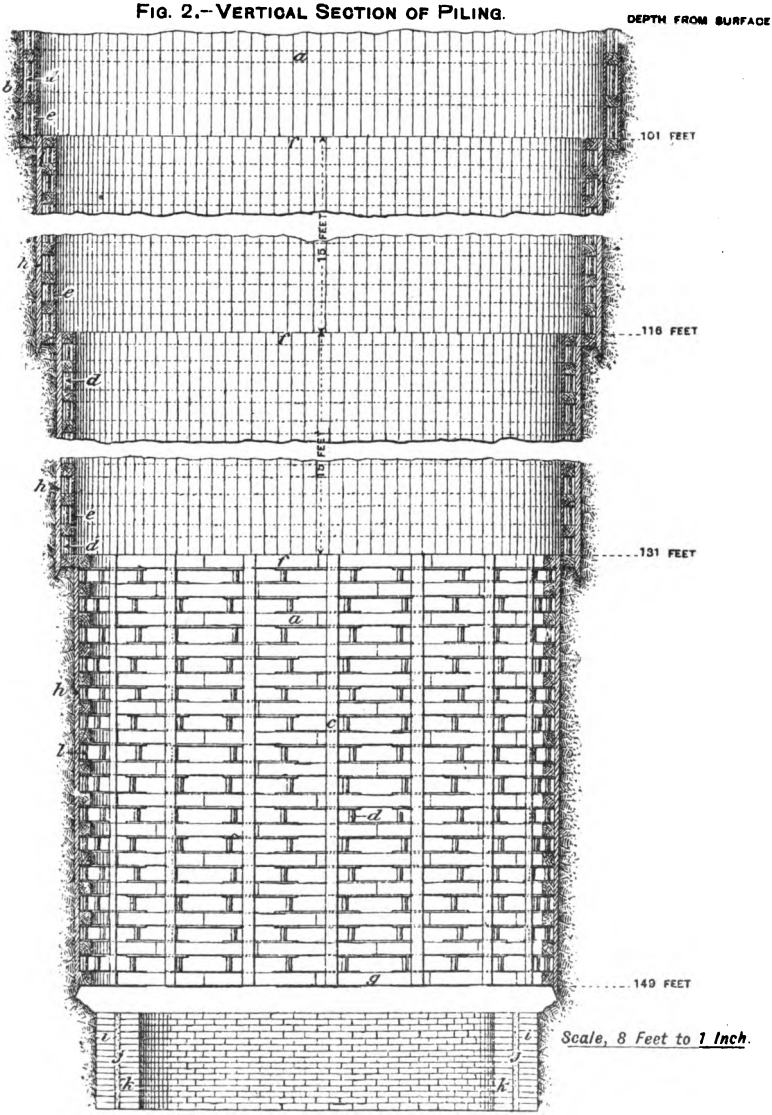
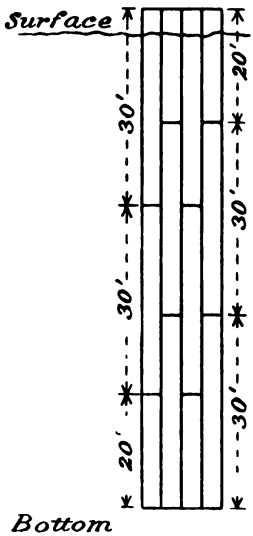


FIG. 126.—Method of Piling and Supporting the Sides of a Shaft at Bowburn Winning, in the County of Durham.

lined with backing deals (*e*), a second crib hung, space being left for another ring of piles, and so on.

The walling of this bad ground was eventually effected with fire-brick lumps in two rings (*i* and *k*), the lumps being 12 inches long by 9 inches wide and 3 inches thick, a space of 3 inches between them being filled with cement grouting (*j*). The space behind the walling was rammed with well puddled clay.



Steel Piling. — Interlocking channel-bar[1] piling, arranged as shown in Fig. 127, and forming (usually) a rectangular lining, is sometimes used instead of wooden piling. In a recent instance inspected by the author the piles were of mild steel, each column being 80 feet long, and built up of two channel-bars of 30 feet each and one 20 feet long, the lengths being arranged so as to break the jointing in respect to the adjoining pile. The piles were driven in by an ordinary pile-driver. Piles of this character can be also applied to circular shafts. The chief difficulty in respect of this and other methods of piling is the preservation of their verticality, unless special means are taken to ensure the same, especially where the clay or gravel contains large boulders.

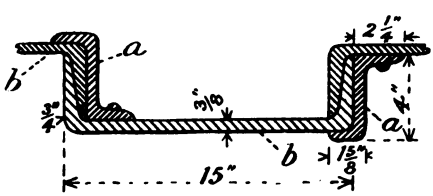


FIG. 127.—Channel-bar Steel Piling.

[1] The Interlocking Channel-Bar Company of Chicago are the makers of this type of girder.

Walker's System of Steel Piling with Guide Rings.—Mr. Charles Walker, the well-known mining contractor, has devised an ingenious system of forcing down piles and lining shafts, which has been successfully

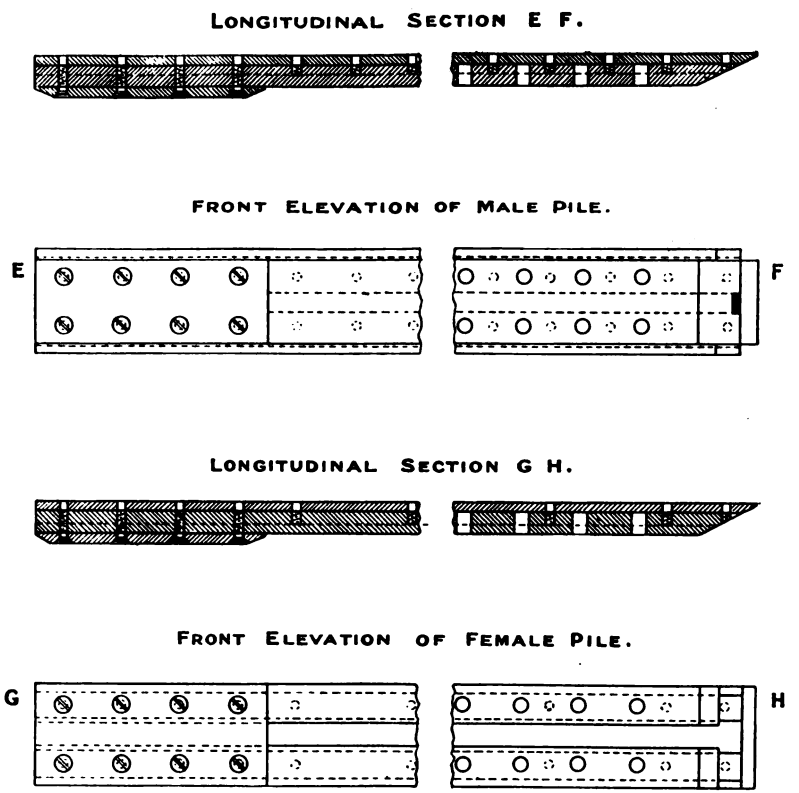


FIG. 128.—Walker's Patent Piles. Longitudinal Elevation and Section of "Male" and "Female" Piles.

applied on several occasions. Briefly, this consists in erecting a cylinder of tubbing which is suspended from a surface staging, and utilising its weight to force down the circle of interlocking piles. The steel piles have riveted to them lugs or brackets against which hydraulic jacks press, the jacks being placed between the lug and the cylinder of tubbing above, the latter con-

stituting the dead or resistance weight for the jacks, and sliding down inside the piles. The piles are of the type known as "male" and "female," and are grooved and tongued with each other, their verticality being assured by means of a movable or "floating" ring of tubbing into which they are grooved and which

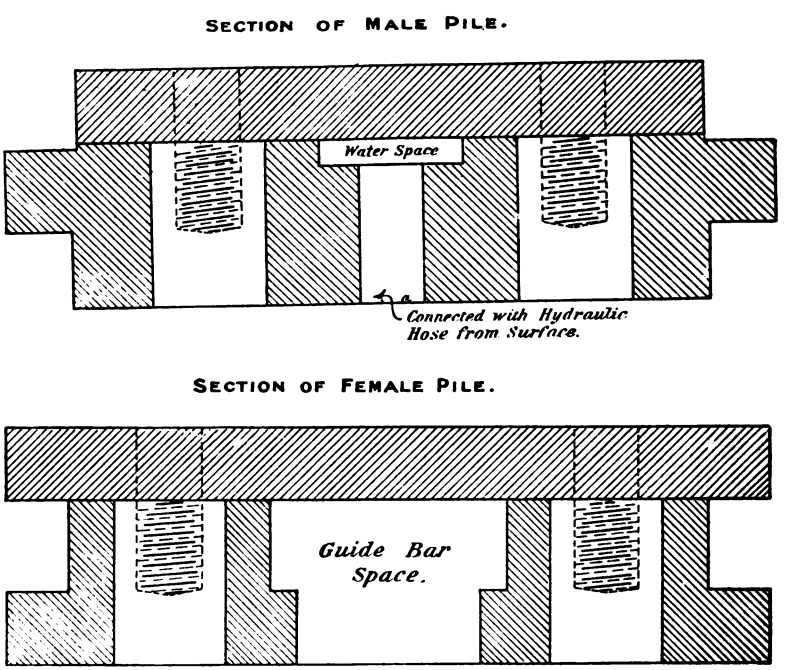


FIG. 129.—Cross Section of Walker's Patent Piles ("Male" and "Female").

lies at the bottom of the shaft, frequently hidden from view as it sinks into the silt. When the piles have been forced into the ground for a depth of about 8 feet, the bottom of the shaft is excavated and another ring of tubbing bolted to the bottom of the sinking column, and so on.

The piles, which are 15 feet long, are of two kinds, "male" and "female," as shown in Figs. 128, 129, and

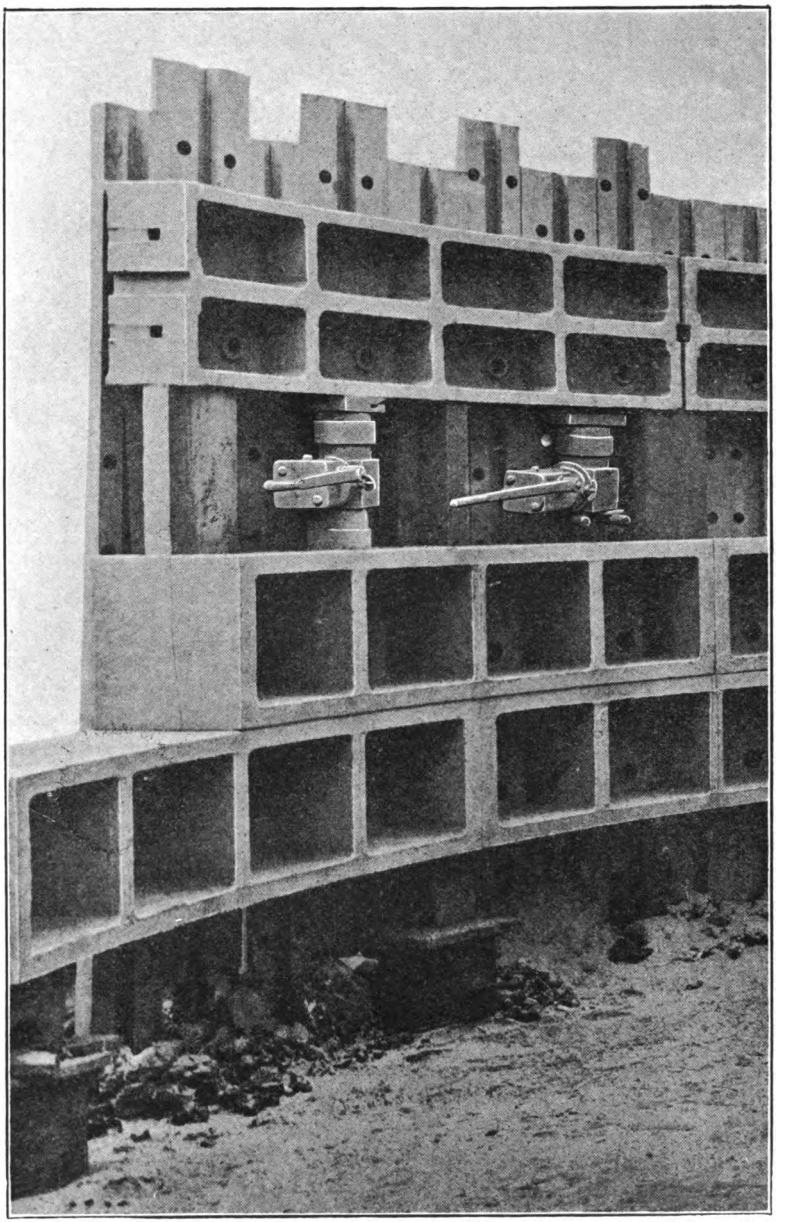


FIG. 130.—General View of Walker's Patent Sand Tubbing and Piles for Sinking through Alluvial Deposits and Quicksands, showing "Male" and "Female" Piles, Pressure Jacks, and Tubbing.

130, the male piles being provided with a central space which carries water, conveyed through the holes (a) by means of the hydraulic hose, to the toe of the pile at 100 lbs. pressure per square inch, or more as required, so

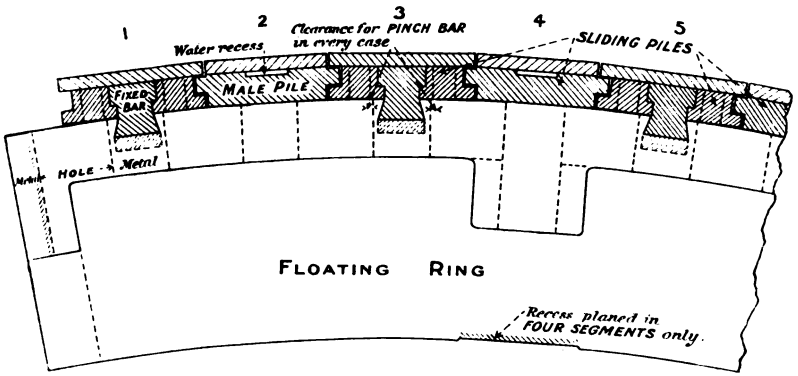


FIG. 131.—Showing Position of the Piles in respect to the Floating Guide Ring. Walker's Patent Piling Arrangement.

easing the descent of the pile. The manner in which the "male" piles are recessed into the "female" piles and their connection to the floating guide ring is clearly shown

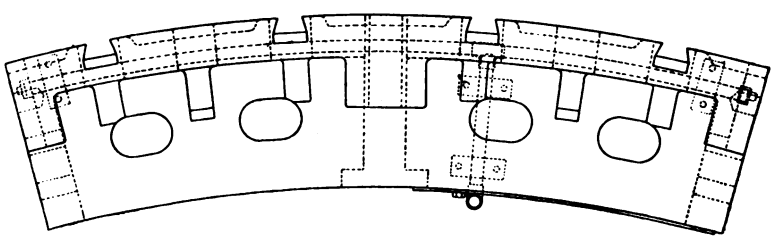


FIG. 132.—Plan of Segment of Floating Ring in Walker's Piling and Sand Tubbing Method, showing Water Piping.

by Fig. 131. The floating ring, which is an ingenious arrangement for keeping the piles in a vertical position, is shown in plan and section in Figs. 132, 133. It is built up of twelve segments, having a tube near the outer

rim close to the piles; this tubing is perforated with $\frac{1}{8}$-inch diameter holes all along its radius, through which water at a pressure of 100 lbs. per square inch is forced in order to wash the sand from underneath the floating ring when the "growth" is too strong to be removed by means of ordinary excavation; thus allowing the ring to be jacked downwards into the fluid sand, and so obtain room for lengthening the main column of tubbing.

In a recent case where the author saw this system being carried out, the segments of cast-iron tubbing, twelve to the circle, were 6 feet $4\frac{1}{8}$ inches long by 2 feet high by $1\frac{1}{2}$ inch thick, with flanges 8 inches deep; the edges were planed, sheet lead being placed between the joints, and the segments bolted together (see Fig. 134).

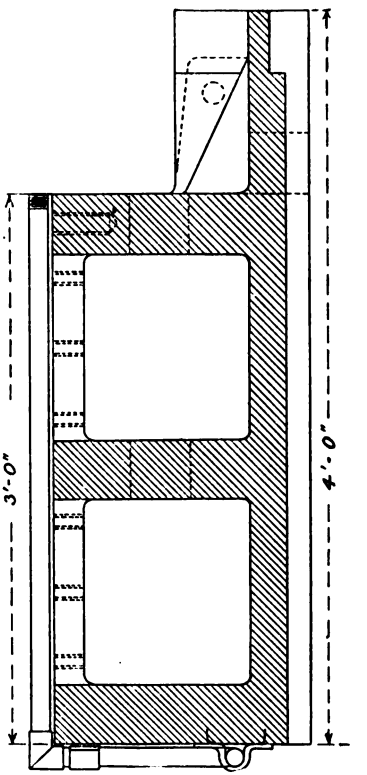


FIG. 133.—Section of Segment of Floating Ring, showing Water Pipe.

The uppermost ring of tubbing is surmounted by a special ring provided with brackets and eye-pieces to allow of the attachment of the suspension-rods which secure the main column of tubbing to the suspension-ring and cradle, which are shown in the general views (Figs. 135, 136). As a considerable strain is exerted on the suspension-ring, it requires for its support a very substantial erection (see Figs. 135,

136) and a strong foundation. It will be found ad-

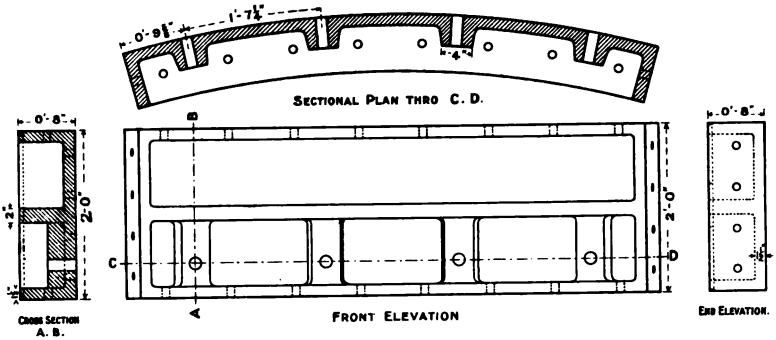


FIG. 134.—Walker's Sand Tubbing. Plan, Elevation, and Vertical and Cross Sections.

visable, therefore, to put down a fairly thick layer of concrete—especially seeing the ground is of an unstable

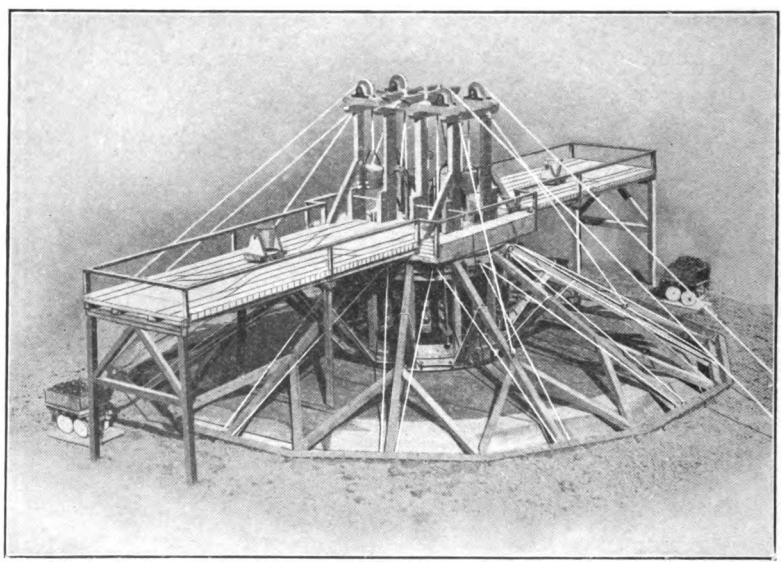


FIG. 135.—Sinking with Walker's Piling and Sand Tubbing. General View of Surface, showing Suspension-Ring, Supports, &c.

character, being composed of alluvial deposits—say an area 60 feet by 60 feet, from which, of course, has to

be deducted the area of the shaft, say 20 feet in diameter. It is advisable also, as the ground in the immediate vicinity of the shaft will have a tendency to cave in, that as little force as possible should be applied

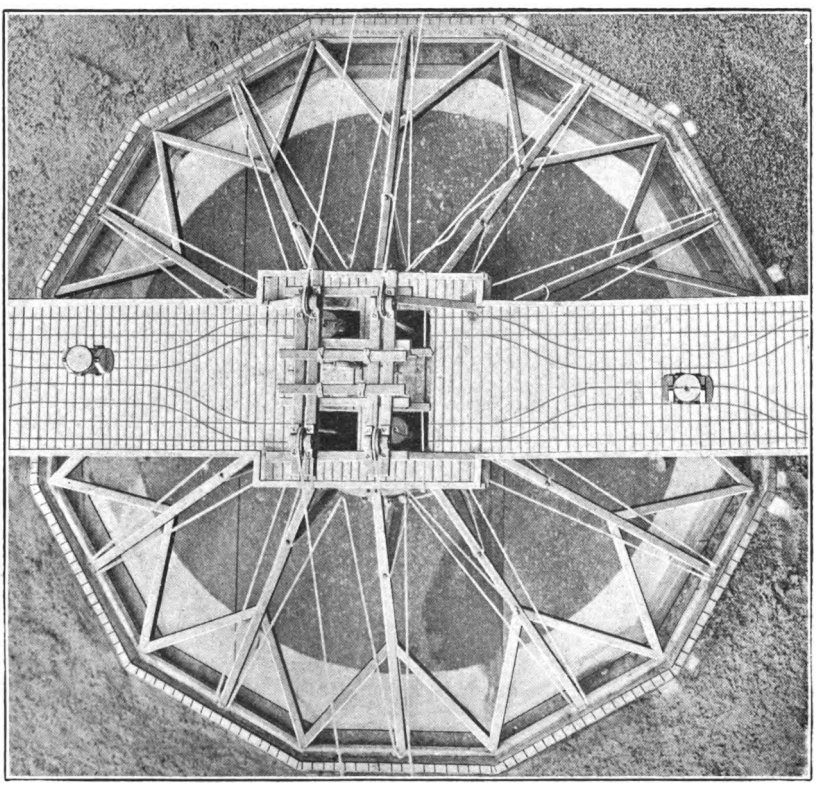


FIG. 136.—Sinking through Alluvial Deposits by Walker's Method of Piling. Bird's-eye View of Surface Arrangements, Suspension-Ring, Supports, &c.

directly to it, hence the reason for carrying the superstructure on struts exerting a pressure in a direction away from the site of the shaft, and placed as near as possible outside the area liable to subsidence, a distance which will be regulated by the depth of the unstable deposit, and its angle of repose or probable fracture.

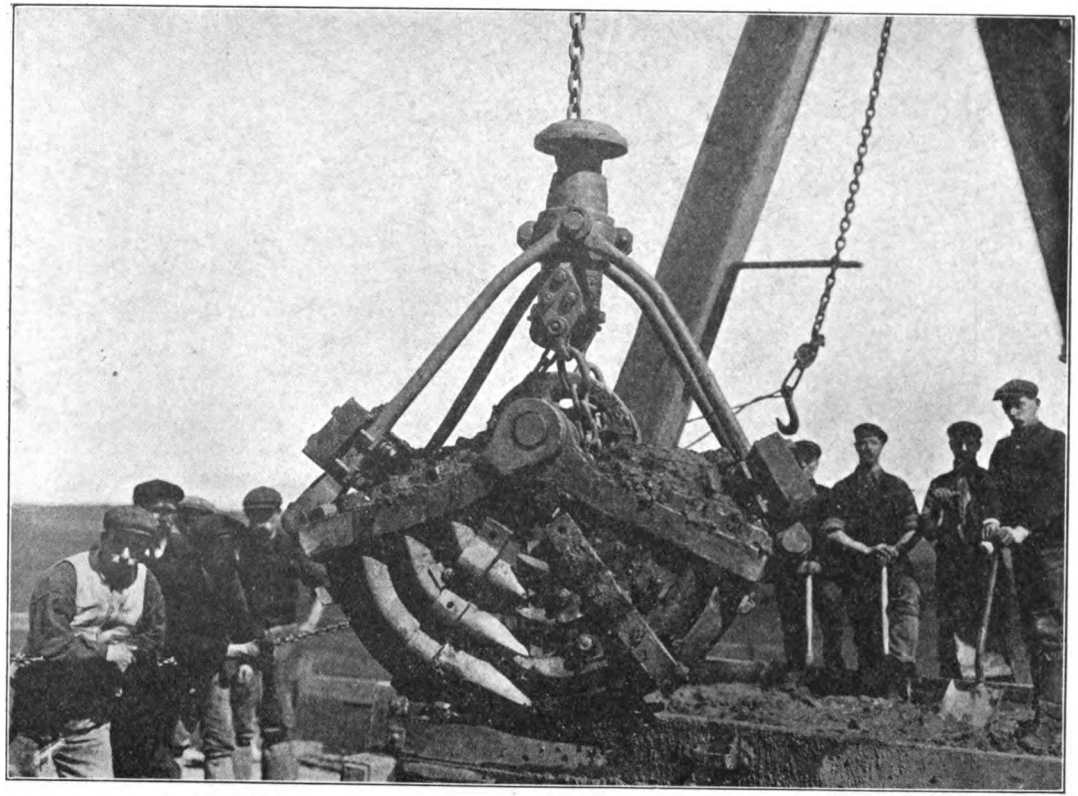


FIG. 137.—Grab for Extracting Soft Ground in Shaft Sinking.

The Sinking Drum Process.—The method of sinking through soft, unstable surface deposits by forcing a cylinder through them and excavating the ground within the same has, with various modifications as to detail, been in operation for many years, but it has remained for Messrs. Haniel & Lueg, of Düsseldorf, to perfect the system.

In its simplest form it consists of an iron cylinder built up of tubbing segments with a cutting shoe attached to its foot, the whole being forced down through the loose and water-bearing strata until the rock-head is reached, the ground being simultaneously sunk through by hand or excavated by a grab (Figs. 137, 139, and 144) or a sack borer (Figs. 145, 146). But Messrs. Haniel & Lueg recommend, that if the shaft cannot be sunk and bricked up in dry work for the first 30 to 50 feet, that the commencement should first be made by means of a masonry shaft (Fig. 138) into which is built a pressure ring in order to obtain sufficient inertia to resist the back pressure of the hydraulic rams, the drop shaft proper being forced down inside of the masonry shaft. Where the depth of loose ground to be penetrated is great, it will be necessary to fit several cylinders into each other. For the purpose of forcing down the cylinder of tubbing, hydraulic jacks are hung to the pressure ring or buttress, which is firmly built into the masonry wall, and forced against the top ring of the tubbing. They are connected to each other by a circular system of tubes, and so arranged that the rams, having advanced the full length of their stroke, can be lifted by hydraulic power, and so allow of further rings of tubbing being put on. The necessary hydraulic pressure is obtained by means of a steam-driven force pump and a hydraulic accumulator, the latter equalising the shocks that cannot be avoided in pumping work, and affords a quiet

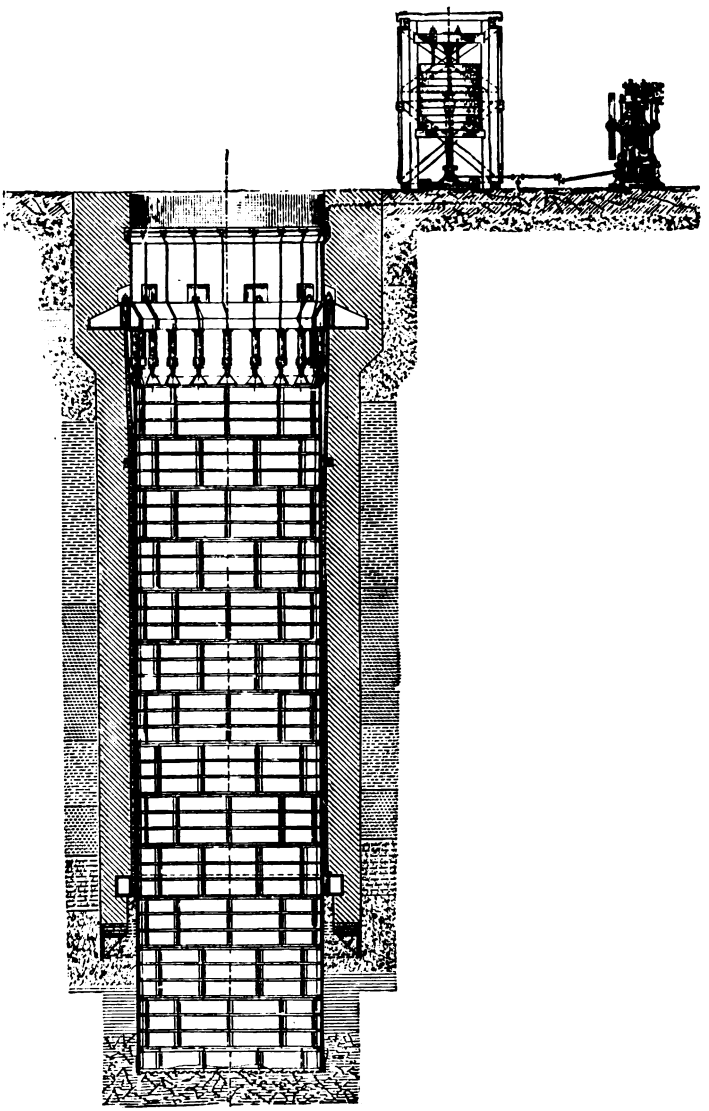


FIG. 138.—Sinking Drum, showing Cylinder of Tubbing being forced down by means of Hydraulic Presses, Accumulator, and Steam Engine. (Haniel & Lueg.)

and constant pressure. In some instances where the work is not large and the strata loose, the use of the accumulator is dispensed with and the jacks are hand-worked.

Fig. 138 shows the whole of the brickwork buttress structure as being below surface level, but it may not be always possible to effect this, especially if the ground to be penetrated is of a silty or sandy character and close to the surface, in which case a part, at any rate, of the masonry shaft will have to be reared above the surface. Fig. 139 is an instance of this. In this case, which shows the application of the method in sinking a shaft in the north of England, having sunk down a short depth, the first thing to be accomplished was the putting in of a block of reinforced concrete, 40 feet square, in the middle of which was the shaft, 21 feet in diameter, the thickness of the block was 3 feet 6 inches, and the reinforcement was carried out by means of a lattice-work of $1\frac{1}{4}$-inch iron rods (*b* and *c*) disposed in the manner shown in Figs. 139, 140. This mass of concrete held the anchor ring (*b* in Fig. 141, and *a* in Fig. 140). The brickwork was then built up on top, the outer circle of anchor rods (*c*) being put in as it rose and tightened at intervals with washers and nuts. When the top was reached the pressure ring (*d*) (Fig. 141) (see also Figs. 144 and 145) was put on and the outer circle of anchor bolts was brought through and finished with nuts, and the main (inner circle) anchor bolt rods (*c*) of 4-inch steel bar were then put in, tieing the pressure to the anchor ring. It will be seen from Fig. 142 that the lower ends of these bolts are T-shaped and are gripped by jaws cast in one piece with the anchor ring segments, whilst the outer circle of anchor bolts passes through holes at the back of the segments.

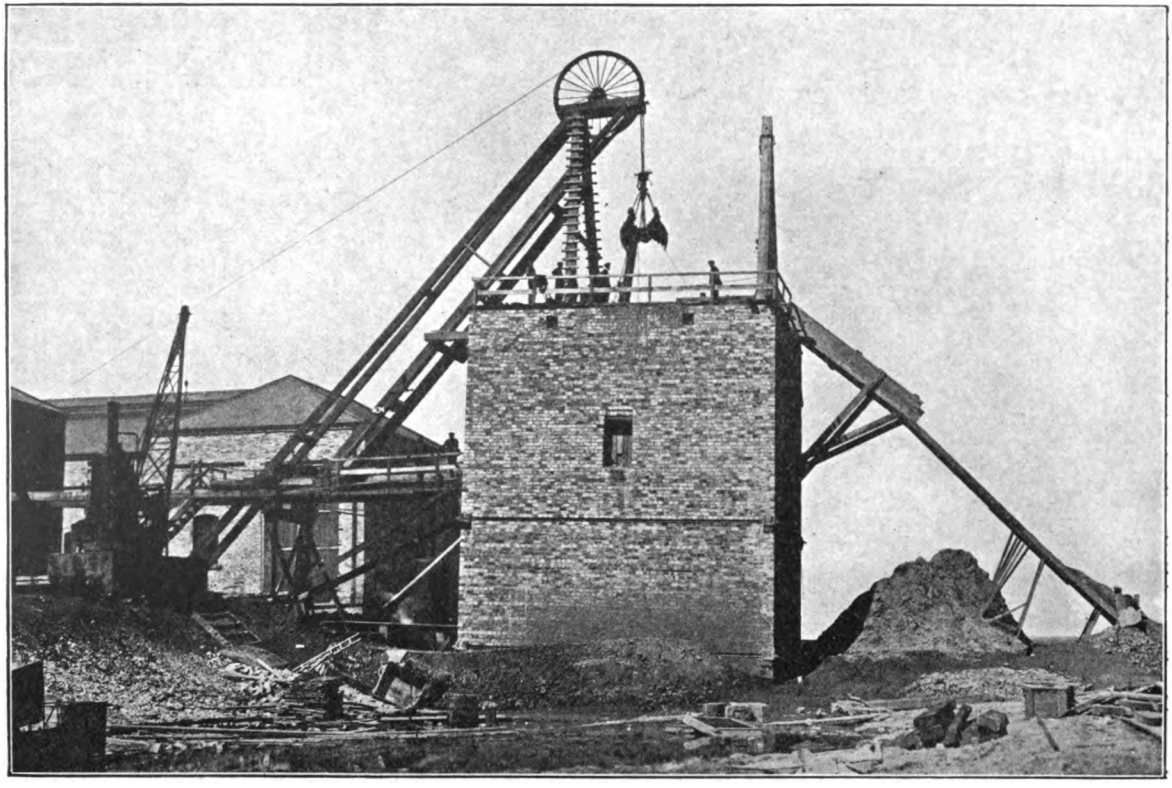


FIG. 139.—Sinking a Shaft by Sinking Drum Process. Brickwork Buttress carried above Surface Level.

The cutting shoe (Figs. 141 and 143) was then built on the floor and the rings of tubbing added until close up to the pressure ring, when hydraulic jacks, thirteen or fourteen in number, were inserted and a pressure of 5 tons per square inch, or say 160 tons per jack, applied to force down the tubbing.

The jacks were bolted to the pressure ring, so that on the pressure being released they should not fall; and as they had a stroke of only 22 inches, small top or "making up" pieces of tubbing had to be used for insertion between the cylinder of tubbing and the jacks. The tubbing proper was 4 feet $11\frac{1}{16}$ inches high by $2\frac{3}{4}$ inches thick. For lifting and lowering the segments a surface electric crane (Fig. 144) travelled round a circular track, elevated above the mouth of the shaft.

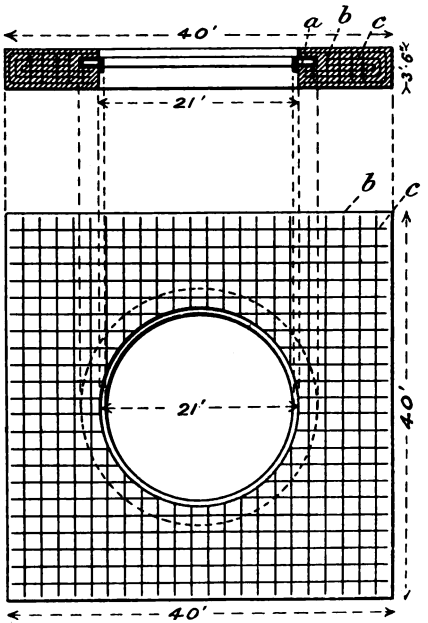


FIG. 140.—Reinforced Concrete Block for holding Anchor Ring. (*a*) Anchor Ring; (*b*) and (*c*) Iron Reinforcing Bars.

Shaft-boring Device for Quicksand. — The Deutsche Tiefbohr-Aktiengesellschaft of Nordhausen are the owners of ingenious arrangements intended for use in sinking shafts through quicksands, where, by means of a continuous flush of water introduced through the shaft lining to the sole, the débris produced in boring out the shaft is carried up to the surface through the

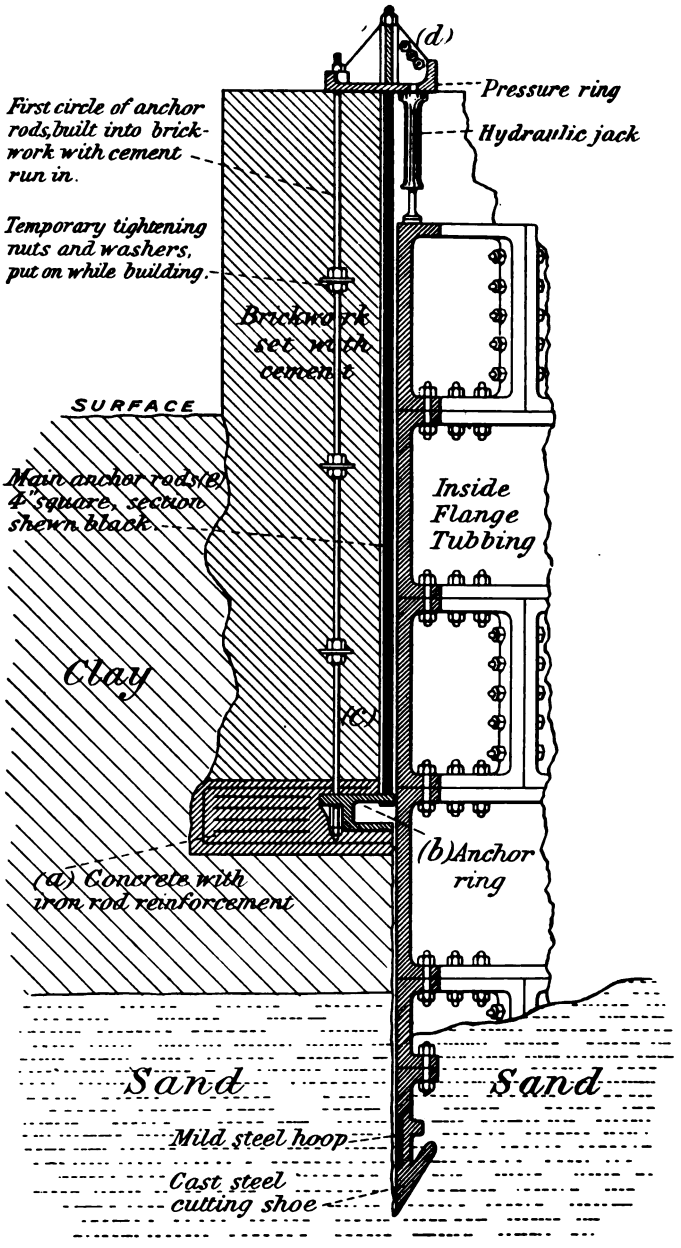


FIG. 141.—Sinking Drum Arrangement as applied in Sinking a Shaft in the North of England.

hollow rods, the water flush greatly facilitating the sinking of the tubbing, as it can be kept going whilst boring operations are stationary and during the insertion of the tubbing; this being effected by a separate distribution of the flushing conduits in the various segments of the tubbing, so that the majority can be maintained in communication with the force pump all the time. The distribution of the water flush all round the periphery of the cutter, together with the powerful support afforded by the action of the boring bit, are features which render this device one of great importance, and its introduction into practical use is an event of considerable interest.

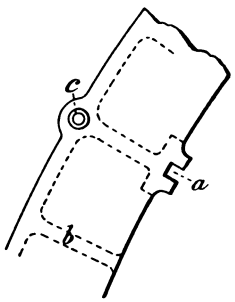


FIG. 142.—Portion of Anchor Ring showing (*a*) Jaw for T-piece of Anchor Bolt of Inner Rods; (*b*) Strengthening Rib; (*c*) Hole for attachment of Anchor Bolt of Outer Rod.

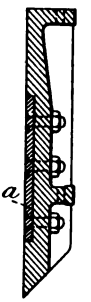


FIG. 143.—Detail of Cutting Shoe. (*a*) Ring of Mild Steel to cover the Joints in the Cutting Shoe.

Means employed of Excavating the Ground within the Sinking Drum

Dredging by Grab or Elevator.—The dredging grab and elevator are sometimes used for the purpose of excavating the ground within the sinking drum, particularly the former; that shown in Fig. 144 is typical of the apparatus.

Extraction of Débris by means of Sacks.—Though very slow in its action, the old sack method of bringing the débris to the surface was very reliable. The sack borer has, however, been greatly improved by Sassenberg & Clermont, the details of their apparatus

being illustrated in Figs. 145, 146; the chief feature being the catching of the débris in sacks which are separately raised without necessitating the withdrawal of the rods or cutting tool. The following description is taken from particulars supplied to the author by Messrs. Haniel and Lueg of Düsseldorf.

The borer is fixed to the end of a column of hollow wrought-iron rods which are rotated by a drill-carriage placed about 20 feet above the shaft mouth and driven by a small engine. Two vertical rails, placed at an angle of 180°, along which the sacks are lowered and lifted by means of iron guide frames, are connected to the borer and boring rods. As the guide rails and also the sack frame and borer are in rotary motion, whilst the sheaves carrying the ropes are fixed, it is necessary to have the sack frames uncoupled during the boring work proper. Coupling and uncoupling is effected by means of a slide suspended from the rope and guided by the rails, this slide carrying at its lower end a long apparatus fitted with pawls. When a full sack is to be raised, the slide, with its pawls set out for action, is lowered, and as soon as the slide tongues touch the bow of the sack frame they open, and, on the slide being hoisted, close and grip the bow of the sack frame, and allow of its being hoisted to the surface. On returning the empty sack, the pawls are again set out for action, and on its arrival at the bottom of the shaft, the tongues again open when striking against the bow of the sack frame, and are fixed in this position by the pawls, so that on the raising of the rope the sack rests upon the bottom of the shaft, and only the slide is lifted. During the rotary motion of the borer the coupling slide loosened from the rope is wedged to the top of the guide rails, joining these in all the motions of the borer.

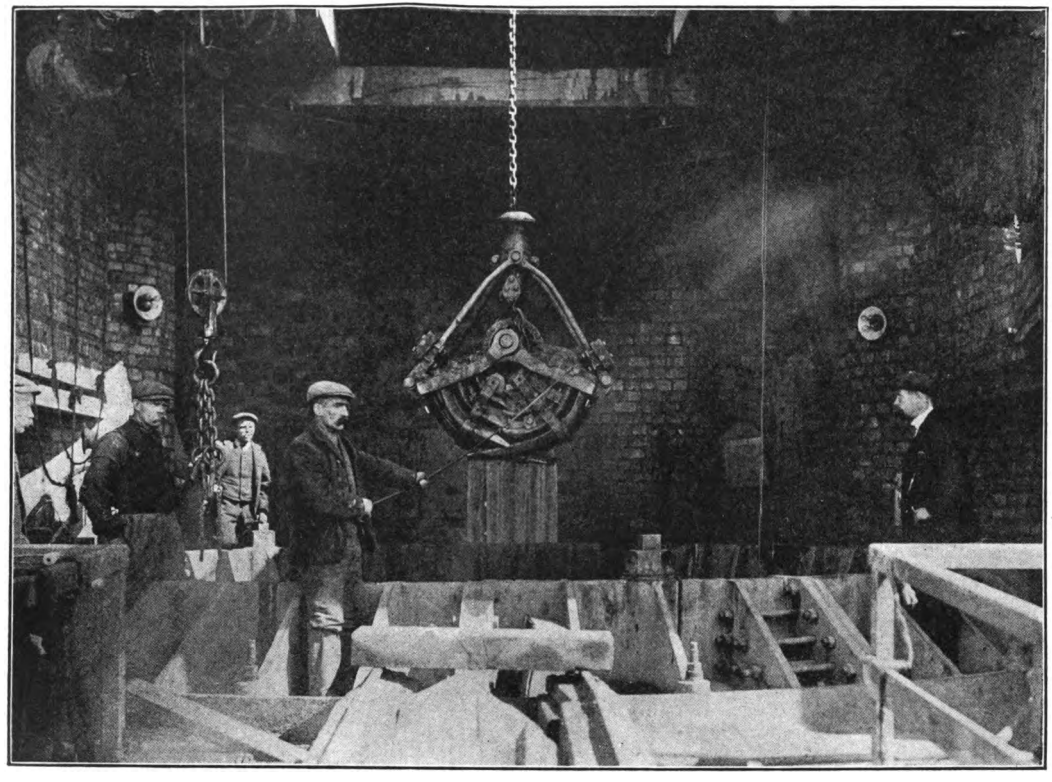


FIG. 144.—Application of the Sinking Drum Process at a Colliery in the North of England. View at the surface, showing Pressure Ring, tops of Anchor Bolts, Travelling Electric Crane and Grab.

Two platform wagons fitted with rails for the dirt tubs are arranged above the shaft for emptying the sacks (Fig. 146 (2)). They are shifted aside when the borer is at work, but are brought close up to the boring rods when the raised sacks are to be emptied. They are also used for suspending the boring rods when a borer is being changed or removed (Fig. 146 (1)).

Haase's System of Sinking through Quicksand.—This consists of driving down a series of wrought-iron tubes placed side by side, through the quicksand, so as to form a lining to the intended shaft. This method was adopted in penetrating the quicksands overlying the lignite seam at the Guerini Colliery (Cottbus district).[1] The seam is 23 feet thick, with a roof of bituminous clay 4 feet thick, above which is 87 feet of quicksand. In sinking a shaft the influx of water and sand was so great that ordinary sinking operations were stopped at a depth of 20 feet from the surface; but work was resumed by the Haase system. The shaft was 10 feet 8 inches by 8 feet 5 inches within the timbering, and was reduced to 9 feet 5 inches by 7 feet 5 inches within the tubular lining, which was composed of tubes 13 feet 1 inch long with internal diameter of 4 feet 1 inch and 2 inches thick. To ensure the verticality of the tubes when driving them down, wooden guides with cast-iron bars at top and bottom were attached to the shaft timbering. The depth to the seam being 71 feet, six courses of tubes were used, and sixty-four tubes to each course, viz. eighteen on each of the long sides and fourteen on each of the short sides of the shaft. It took 225 working shifts of 12 hours each to complete the work. The total length of tubes inserted was 4440, and the total cost (work and material)

[1] "Schachtabteufen nach dem Verfahren von Haase," *Zeitschrift für das Berg-Hütten und Salinen-Wesen*, vol. xxxvi., 1888, pp. 225–226.

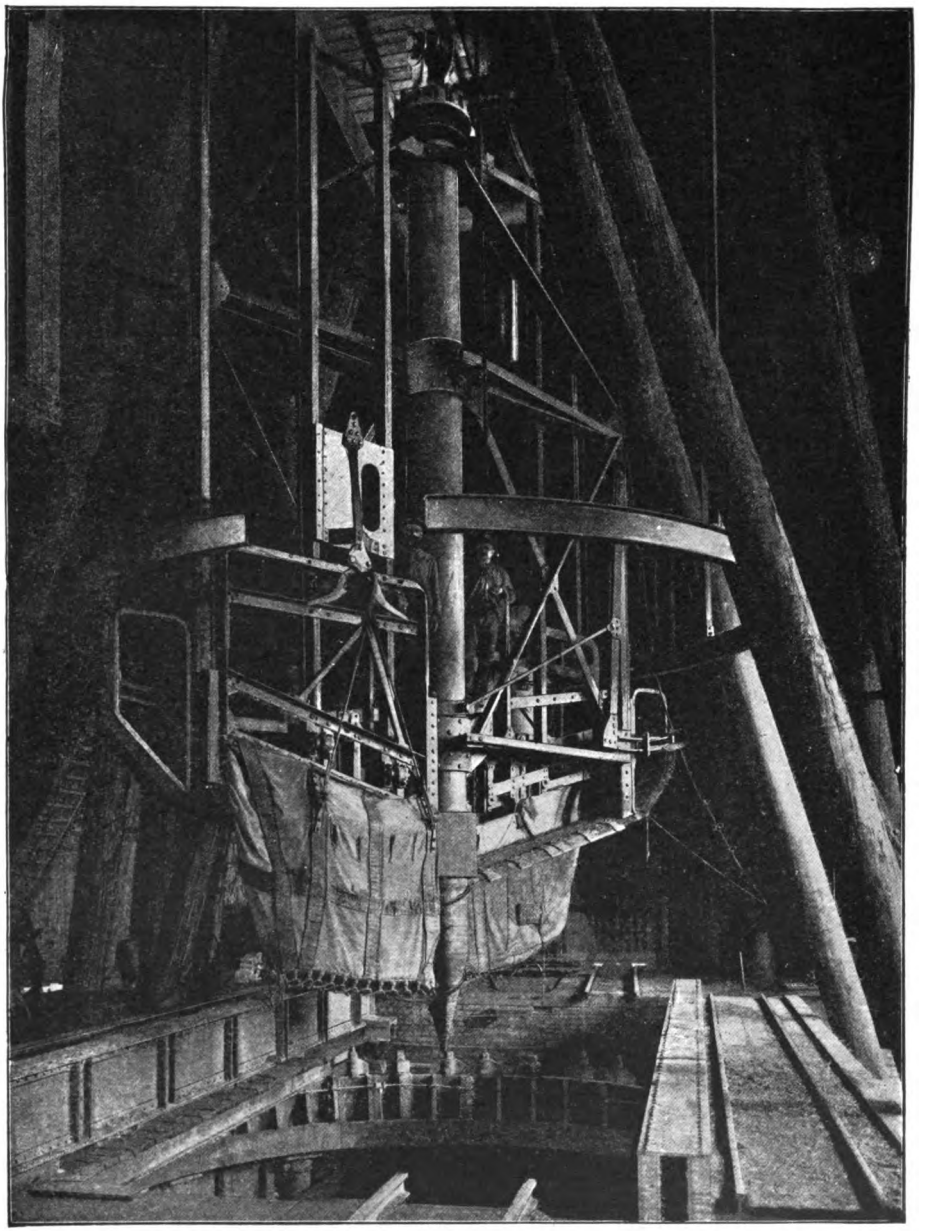


FIG. 145.—General View of Sassenberg & Clermont's Sack Borer. From Reimer's *Shaft-sinking in Difficult Cases*, by permission of Messrs. C. Griffin & Co.

was £2102, 11s. 3d., or 9s. 5·65d. per foot of tube inserted. After the insertion of the tubes the work of removing the sand and erection of the permanent iron tubbing was proceeded with.

The Honigmann System of Boring and Sinking Shafts.—The object of this, like other methods of subaqueous shaft-sinking, is the saving of pumps, but in addition thereto it secures the uninterrupted raising of the débris. The system is particularly applied to sinking through loose ground. The principle on which it is worked consists in making the water-level in the shaft higher than the natural water-level of the strata, and raising the specific gravity of the liquid within the shaft, by the addition of clay, from 1 to 1·2. The effect being to support the sandy sides of the shaft and, together with the application of compressed air, to raise the sludge to the surface.

Having sunk a shaft by ordinary means to a depth of from say 30 to 60 feet, the apparatus shown in Fig. 147 is erected, consisting of the boring mandril (*a*) hanging from the hoop and plate (*b*), to which the rope for raising or lowering the rods is attached; *cc* are friction-reducing pulleys; *d*, *e*, *f*, *g*, *h* is the driving gear, and *i* the boring carriage. The boring mandril (*a*) carries the hollow rod (*k*), to which is attached the revolving arrangement (*l*), *s*, *t* is the boring tool, *m* the tubbing cylinder, the bottom of which reaches underneath the natural water-level; *r* is the compressed-air tube, *n* the horizontal pipe, *o* leather hose, *p* sludge box, *q* water and clay supply box.

The rotation of the hollow rods contributes to the formation of a syphon, and by the higher water-level and pressure in the shaft the sludge is pressed to the bottom and into the boring rods. By forcing compressed air

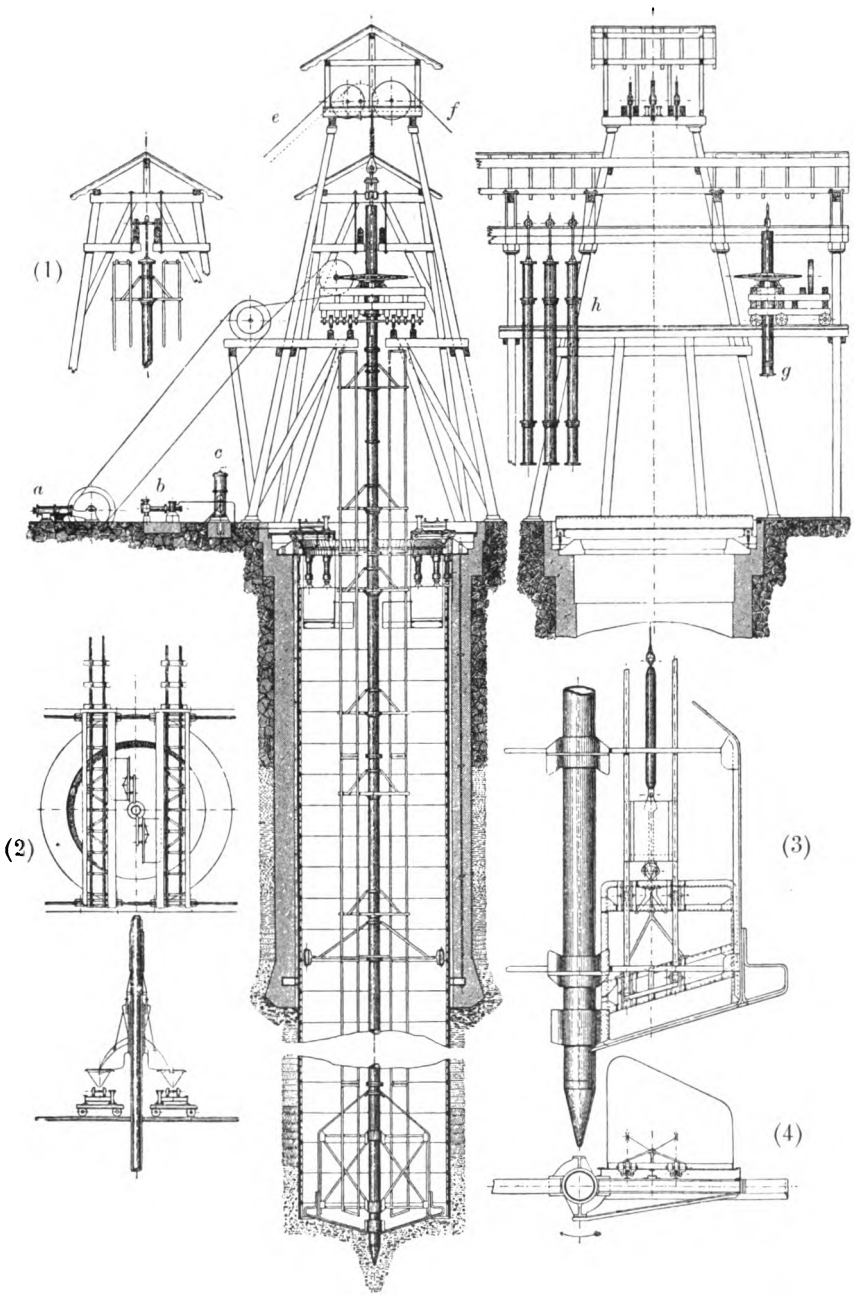


FIG. 146.—Sinking with Drum Shaft and Sassenberg & Clermont Boring Appliances at the Adolf Shaft of the Eschweiler Mining Co.

(1) Suspended Boring Rods; (2) Travelling Platforms with Rails for emptying the Sacks and catching the Rods; (3) Sack Borer with Catching Slides; (4) Sack.

(*a*) Steam Engine; (*b*) Pressure Pump; (*c*) Accumulator; (*d*) Boring Carriage; (*e*) Winding Rope; (*f*) Boring Rope; (*g*) Borer run out; (*h*) Suspended Boring Rods. (Haniel & Lueg.)

through the central tube, the necessity of having a water-level in the shaft higher than the level of the sludge delivery pipe is obviated, the mixture of air, water, and sludge having a less specific gravity than the clayey water in the shaft.

According to the late Mr. M. Walton Brown, two shafts at Heerlen, in Holland, were by this method successfully sunk through the recent formations overlying the Coal-Measures; the thickness of these formations being 223 feet down to the Tertiary marl, and no lining whatever was used; and the farther sinking of the second shaft was continued, and the very loose-running Greensand pierced without any accident. The No. 1 shaft was sunk into the Coal-Measures at a depth of 330 feet in March 31, 1897.

The Pattberg Percussive Borer.—This method, which was used with such good results in the sinking through the Tertiary beds, at the Rhein-Preussen Colliery, of Nos. 4 and 5 shafts,[1] consists in operating a large borer—as wide as the diameter of the finished shaft—and at the same time forcing water under pressure down to the lower end along channels in the same, and so flushing out the bottom of the shaft, the débris being raised by means of compressed air. In Fig. 148, (1) and (2) show the type of borer first used at the Rhein-Preussen sinking, weighing 9 tons, the vertical height being 27 feet, and having a cutting face 21 feet in length. In Fig. 148 (2), *r* represents a V-shaped, wrought-iron block carrying the teeth and pierced with holes *aaa* on both sides; *bbb* are a number of small tubes connected to channels *zz* in the cutting teeth. The tubes *a* are

[1] "Das Stossbohrverfahren von Pattberg und seine Anwendung beim Abteufen der Schächte IV. und V. der Zeche Rhein-Preussen in lockerem Gebirge," by L. Hoffmann, *Glückauf*, 1902, vol. xxxviii. pp. 553–556.

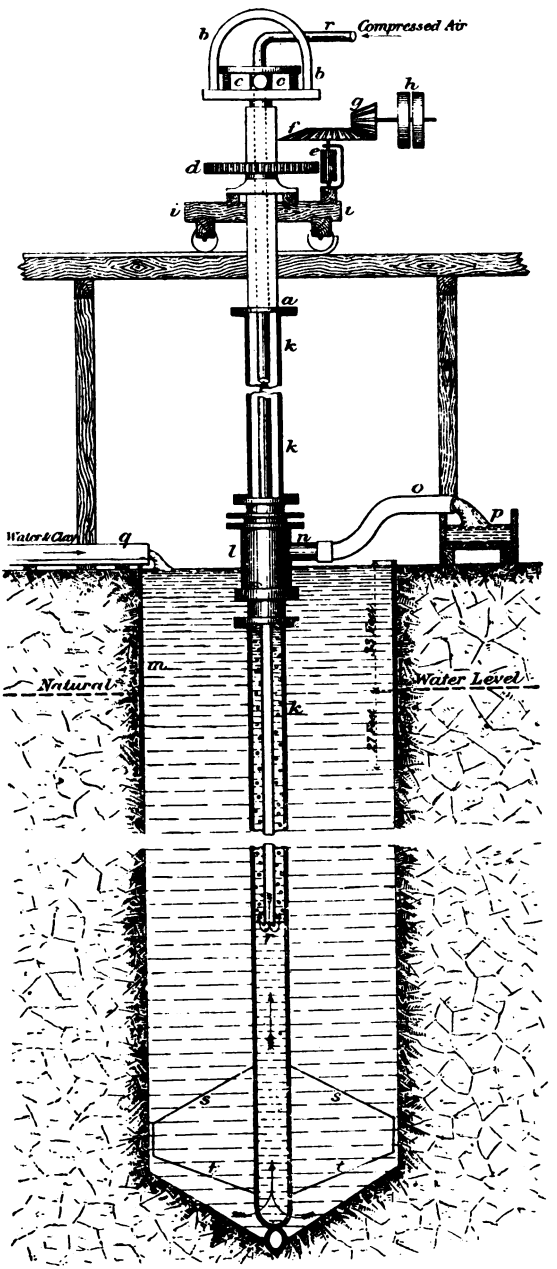
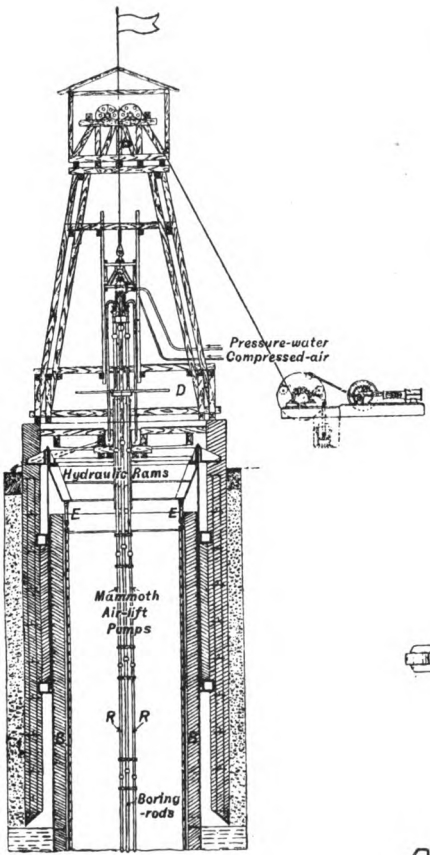


FIG. 147.—The Honigmann System of Boring out Shafts.

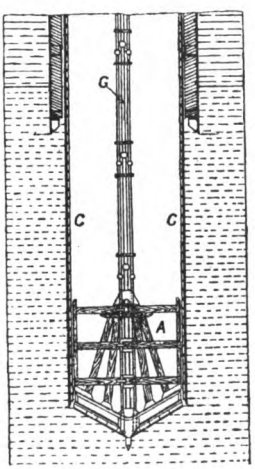
connected to the hollow boring rod G, and through these the flushing water is squirted out at the bottom of the shaft; *u* is a vertical and *v* a horizontal guide, which, together with the struts, were, in the form first used, made of wood, but in the more recently constructed borers they are of iron. The two pipes RR, $5\frac{1}{2}$ inches diameter, surround two other pipes 4 inches diameter, the annular space being connected with a compressed-air main. The compressed air issuing into the inner pipe of the air-lift pump R close to the bottom, gathers the débris from the deepest part of the shaft bottom, and forces it up the inner tube mingled with water. At the Rhein-Preussen sinking the air was compressed to 1100 lbs. per square inch, and the hydraulic pressure of the water in G was 1000 lbs. per square inch. At the same place the borer had a length of stroke of from 8 to 12 inches, and was worked at from sixty to seventy strokes per minute.

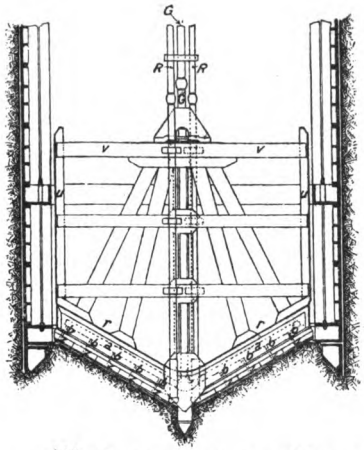
Whilst the boring proceeds, the caisson, built up of segments of tubbing, and provided with a cutting edge, is forced downward by hydraulic jacks in the manner which has already been described.

It will be seen that the system is peculiarly adapted to sinking through loose strata. The conditions existing at Rhein-Preussen Colliery are worthy of mention, as they present features of peculiar interest. The surface deposits were very difficult to sink through, consisting of alluvial beds very open and full of water. The sinking of the No. 1 shaft to the Coal-Measures by ordinary means occupied no less than twenty years, the final diameter of the shaft being 8 feet 10 inches as compared with an original (at the commencement) diameter of 24 feet 9 inches. No. 2 shaft took nine years to sink by ordinary means, the original diameter being 32 feet 5 inches, which was finally reduced to 14 feet.

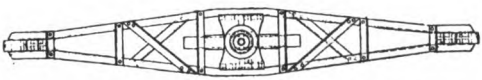


(1) SECTION OF SHAFT.

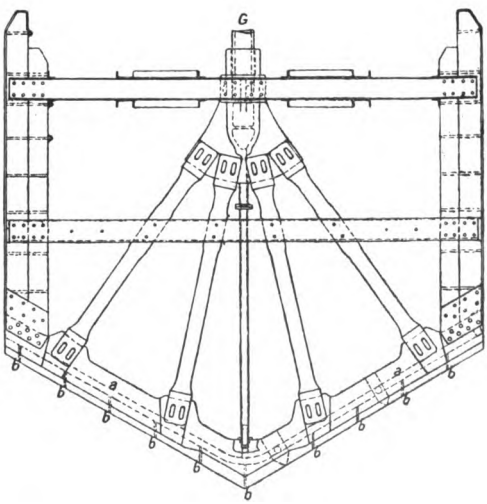




(2) SIDE-ELEVATION OF WOODEN PERCUSSIVE DRILL.



(3) PLAN OF IRON PERCUSSIVE DRILL



(4) SIDE-ELEVATION OF IRON PERCUSSIVE DRILL

FIG. 148.—The Pattberg Percussion Borer.

The application of the Pattberg system proved eminently satisfactory in boring through soft rocks, due largely to one of the principal features of the invention—viz. the continuous removal of the débris by the aid of the mammut pumps. The rate of drilling was on the average $3\frac{3}{4}$ feet *per diem*, estimated as being three times quicker than by dredge and five times as quick as a rotary drill. The maximum speed attained was $16\frac{1}{3}$ feet. How far this method would be successful in boring through hard water-bearing rocks it is difficult to say, the present writer not being provided with information as to actual practice in this respect.

The total cost of the plant may be put at about £10,165, the chief items of which are as follows :—

Percussive drill	£840
Rods and mammut pump	585
Engine and drilling plant	765
Hydraulic presses	1225
Cost of erection of sinking engine	1500
Tubular boilers and fittings	1725

CHAPTER IX

METHODS OF SINKING SHAFTS THROUGH WATER-BEARING ROCKS, WHETHER HARD OR SOFT, AT THE SURFACE OR OCCURRING AT DEPTH

The Pneumatic or Compressed-air Method—sometimes known as the caisson process.

This method of sinking through quicksand came into notice after the successful application of the process by M. Triger in France, about fifty-five years ago. It consisted in forming a cylinder of cast-iron by adding ring after ring at the surface, like a column of Chaudron tubbing, and gradually sinking the same by excavating the ground at the bottom of the shaft. In order to prevent the water entering from the surrounding beds, compressed air was conducted into a chamber at the bottom of the cylinder, which was partitioned off from the rest of the cylinder by a horizontal diaphragm. Above this again was another and smaller air-tight compartment, to allow of the persons when leaving or commencing work to pass from or to the base of sinking operations, and also to allow of the passage of the kibble without affecting the air pressure at the bottom (see Fig. 149).

Applied at Bettisfield Colliery.—The Bettisfield Colliery in North Wales was sunk some years ago for a depth of 102 feet by Mr. Arnold Lupton[1] by an adaptation of this method (see Figs. 150, 151, 152). In this instance the cylinder was 13 feet in diameter, built

[1] *Mining*, by Arnold Lupton, M.I.C.E., F.G.S., &c., first edition, pp. 132–133.

up of cast-iron plates with internal flanges, which were bolted together and the joints wedged to make them water-tight. The cutting edge, also of cast-iron, at the bottom of the cylinder had a flange on which was built a bell-shaped erection (Fig. 151), the top of which was 6 feet in diameter, from which was carried a tube of like diameter, at the top of which was the air-lock, with two trap-doors, one opening downwards and communicating with the atmosphere, and the other into the 6-feet tube. The compressed air was carried into the tube by means of the inlet *a* (Fig. 152). Any water that found its way into the shaft in spite of the compressed air was forced to the surface through 3-inch tubes. As the force exerted by the compressed air tended to lift the bell, it was found necessary to let the air-pressure out to allow of the descent of the cylinder, and in order to assist towards this bricks were placed in cross bars between the 6-feet and the

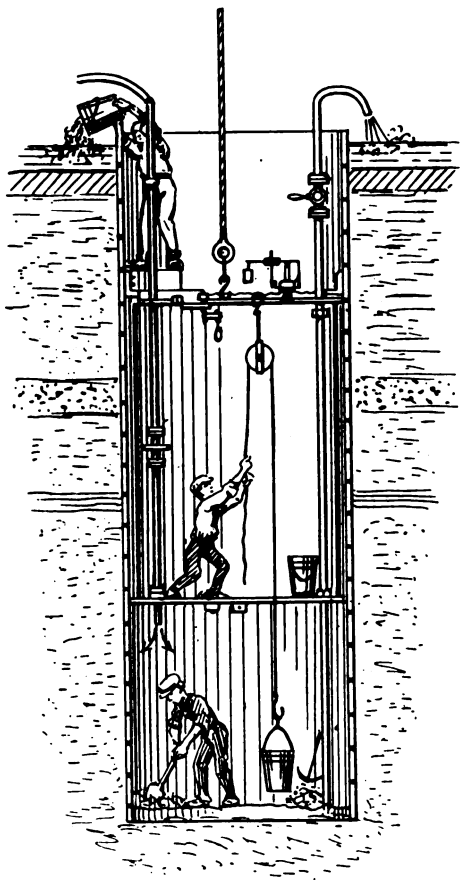


FIG. 149.—Sinking a Shaft under Water by the Triger Method.

13-feet cylinders. After the cylinder had been lowered about 2 feet, the compressed air was readmitted, forcing out the water, and sinking resumed. When passing through some clay and gravel the cylinder stopped, so

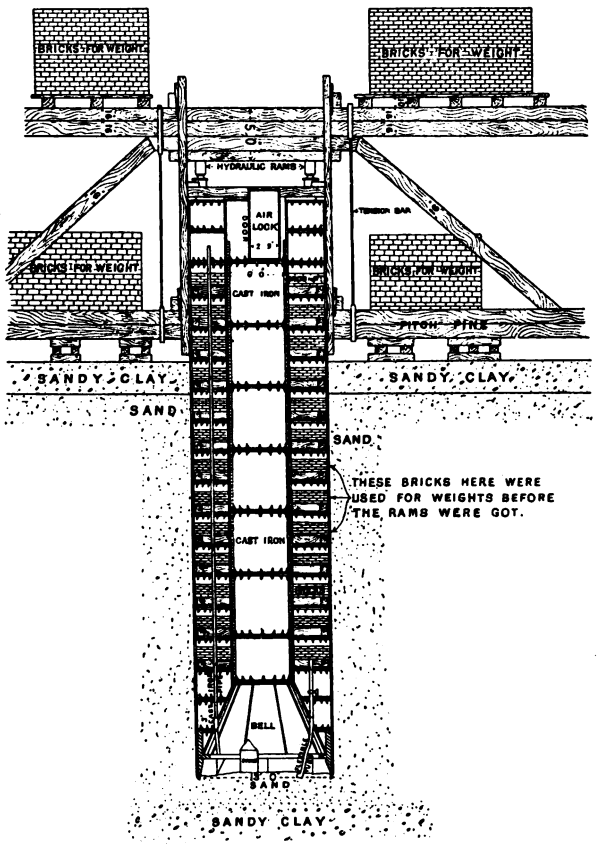


FIG. 150.—Pneumatic Sinking, showing Application of a Hydraulic Ram. (From Lupton's *Mining*.)

that hydraulic rams, six in number, each one of which was capable of exerting a force equal to 60 tons, were applied to force it down; the back resistance or buttress for the rams being in the nature of a large wooden framework held down partly by attachment to piles

and partly by the weight of bricks placed upon it (see Fig. 150). On reaching the stone-head a wedging curb was set, and tubbing plates carried up therefrom to the underside of the flange, to which the bell was fixed, and the latter and the 6-feet tube removed.

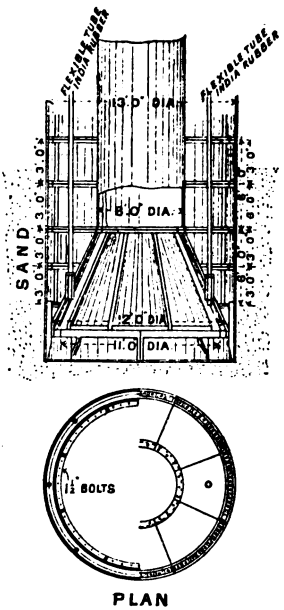


FIG. 151.—Pneumatic Sinking. Bell, Air-cylinder, and Tubbing. (From Lupton's *Mining*.)

As applied in Sinking Shafts through Sand at Ardeer, Ayrshire.[1]—During the period December 1904 to November 1905 two shafts were sunk to a depth respectively 85 feet and 90 feet 5 inches, chiefly through sands and clay, by compressed-air caissons. In the arrangement adopted the man-lock was at the side of the tube on top of the diaphragm, and was 6 feet high by 3 feet wide, being capable of holding comfortably four or five men. The inlet and outlet doors were 2 feet 6 inches high by 1 foot 8 inches wide, being lined with rubber joints. At the top of the locks were two cocks, $\frac{5}{16}$ inch and $\frac{3}{4}$ inch diameter, for the admission of the compressed air from the caisson. The material lock for the débris was placed at the top of the tube. The caisson consisted of a steel shell $\frac{1}{2}$ inch thick and 17 feet 7 inches external diameter, and was lined within with 18-inch brickwork, 3 inches of concrete being placed between the brickwork and the steel shell. The internal diameter of the finished shafts is 14 feet.

[1] "Description of the Sinking of Shafts through Sand at Ardeer, Aryshire, by the Pneumatic Process, &c," by Thomas H. Mottram, H.M. Inspector of Mines, *Trans. Inst. M.E.*, vol. xxx. pp. 205–234.

When started at water-level, a pressure of 7 lbs. per square inch above atmosphere was maintained, which was increased to 22 lbs., until the shafts passed through the water-bearing strata, but after getting into the clay it was found possible to lessen it, as the percolation of the water was much less.

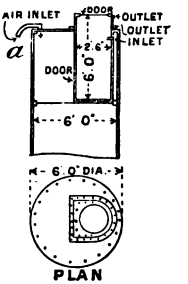


FIG. 152. — Pneumatic Sinking. Air-lock. (From Lupton's *Mining*.)

The weight of the caisson itself with its accessories was found sufficient to sink it to a considerable depth, but after a time it was found necessary to greatly increase the weight. Thus, when that at No. 1 shaft had attained a depth of 54 feet, weight had to be added, and when at a depth of 79½ feet it totaled 784 tons, made up as follows:—

Pig iron	480 tons
Steel shell	52 ,,
Brickwork and concrete . . .	234 ,,
Deck and air-lock	18 ,,
Total . . .	784 ,,

The compressed-air method can be advantageously applied in cases of limited depth, the one adverse feature being the impossibility of utilising it in depths much over 100 feet, because, speaking generally, a pressure of 45 lbs. per square inch, or three atmospheres above the normal pressure of the atmosphere, is about as much as men can endure for any length of time. At the Maria Colliery, however, near Aix-la-Chapelle, a thickness of 121 feet of quicksand was sunk through, the greatest air pressure being 3·2 atmospheres (47 lbs.), the work being accomplished in 228 days, and the men working in the compressed air experienced no ill effects.[1] And in 1868 shafts were

[1] *Zeitschrift für das Berg-, Hütten-, und Salinen-Wesen im Preussischen Staate*, 1885, vol. xxxiii. p. 221; and *Trans. N.E. Inst. M.E.*, 1887, vol. xxxvi. ab. p. 35.

sunk at Trazegnies, in Belgium, the maximum pressure being 3·12 atmospheres.[1]

As the health of the men suffers not only from the abnormal pressure, but from the changes of pressure, they should rest in the air-lock for some time both before entering and after leaving the bottom of the shaft.

Cost of Sinking by the Compressed-air Method.—A shaft sunk at Havré Colliery through running sands and water-bearing chalk 126 feet thick cost £888, 19s. per foot, and was accomplished in four years.[2] Another at La Louvière Colliery, sunk through 42 feet of quicksand, cost £98, 3s. per foot, the work being accomplished in two months.

Precautions.—The following precautions should be taken in connection with sinking by the pneumatic method: The air used for compressing should be as pure as possible, for which reason the compressing machinery should not be in the vicinity of gasworks, burning pit-heaps, lime-kilns, and the like. Illuminating gas should not be used in the compressor-house because of the defilement of the atmosphere, and liability to escape of the gas. The machinery should also be kept some distance from the screens, and all precautions taken to avoid the admixture of coal dust in the compressed air. Every precaution should be taken by having the air-cylinders well jacketed with water to prevent spontaneous combustion of deposits formed in pipes and receivers; and mineral oils of low flashing-point should not be used for lubricating the air-compressing cylinders.[3]

[1] *Trans. N.E. Inst. M.E.*, 1887, vol. xxxvi. ab. p. 35.

[2] *Annales des Mines*, series 8, vol. viii. p. iii; and *Trans. N.E. Inst. M.E.*, vol. xxxv. ab. p. 33.

[3] "Report of the Committee appointed to inquire into the Explosion of an Air Receiver at Ryhope Colliery," by M. Walton Brown, *Trans. N.E. Inst. M.E.*, 1888, vol. xxxvii. p. 204.

The Kind-Chaudron Method of Sinking and Lining Shafts.—The practice of boring out shafts emanated from the Continent, where Herr Kind was

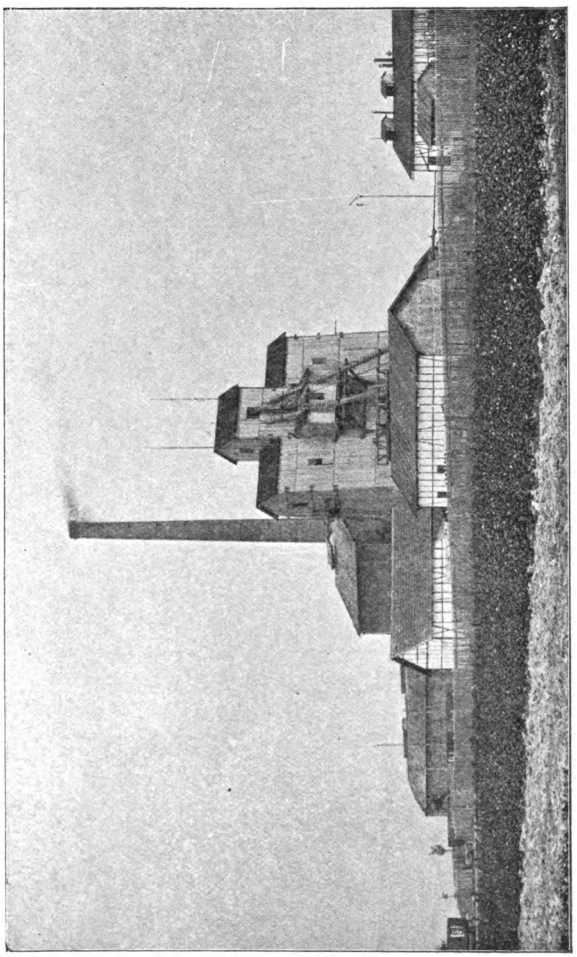


FIG. 153.—General Surface View of a Kind-Chaudron Sinking.

the first to do this, boring shafts under water to the required size in one operation, and using free-falling cutters in the same manner as in putting down ordinary bore-holes. Later, the process was carried on in two

or more stages by a shaft of smaller diameter being bored out in advance of the larger one. Chaudron, the designer of the tubbing of the same name, became associated with Kind in his sinking operations, and their combined process of sinking and lining of shafts is known as the Kind-Chaudron method.

The Kind-Chaudron Process.—The various and successive stages of the process are—

(*a*) Alternately boring a small pit in advance and enlarging it with a bigger tool to the full size of the shaft.
(*b*) The preparation of a seat for the moss-box or water-tight joint on which the tubbing is erected.
(*c*) The lowering of the moss-box with the water-tight tubbing (*cuvelage*) above it.
(*d*) Putting in the outside lining of concrete.
(*e*) Pumping out the shaft.
(*f*) Undersetting the moss-box.

The appliances used chiefly consisting of—

(*a*) A *baraque* or "housing," which is an extensive erection (see Fig. 153), in which are contained—
(*b*) The engine and rocking lever.
(*c*) The spears or boring rods, with free-fall arrangement (see vol. i., "Boring").
(*d*) Tools such as the small and large "trépan," or chisel, a sludger, and tools for catching tools or broken rods.
(*e*) Rings of tubbing (*cuvelage*), moss-box, and concrete backing appliances.

Boring out the Shaft.—The boring out of the shaft is effected in at least two successive stages. At

first a cylindrical hole, 4 to 9 feet[1] in diameter, is bored, which usually is kept 30 to 36 feet in advance of the wide or full-sized sinking to which it is enlarged at separate times. The pitch-pine rods carrying the

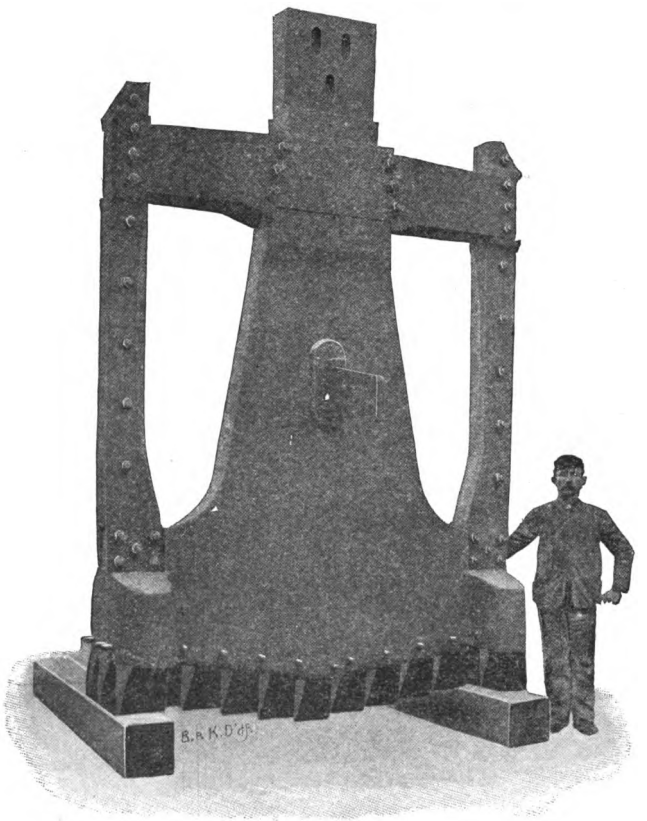


FIG. 154.—Small Cast-iron Trépan.

cutting tool or trépan are suspended from the end of a great balancing beam, of the simple lever type, stationed at the surface, worked up and down by the action of a special steam cylinder. In each case the

[1] The diameter of the preliminary borer has been increased of late years from 1·4 to 2·5 metres, and that of the widening tool to 4·8 metres.

cutting tool or trépan consists of a horizontal wrought-iron bar (sometimes of cast-steel), to the under surface

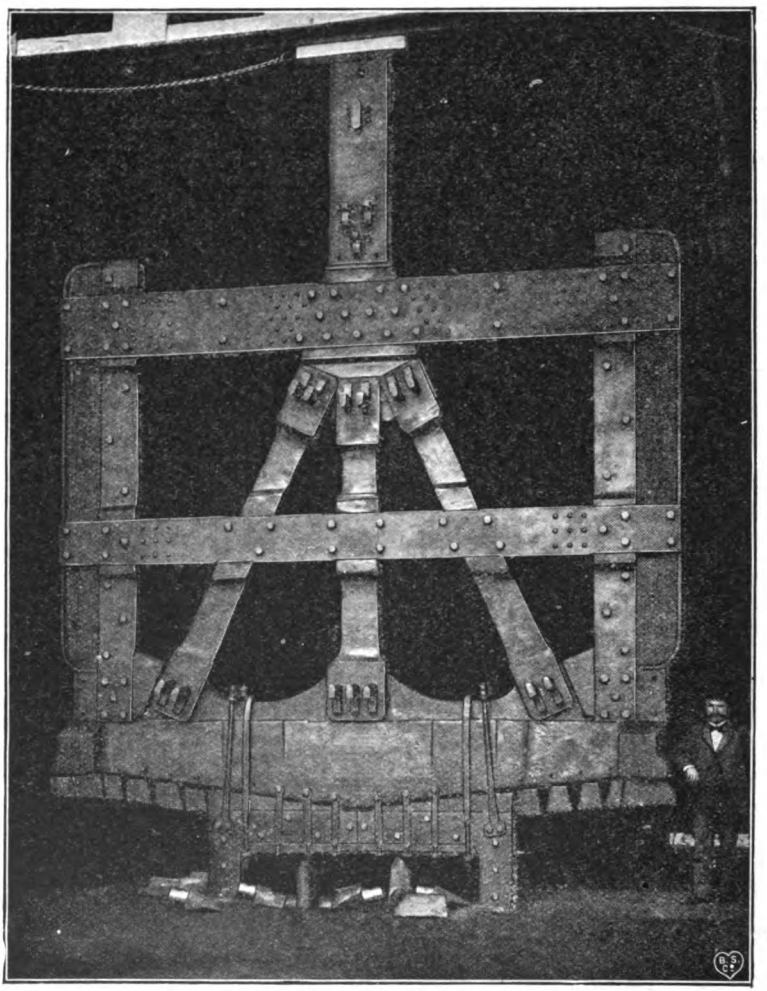


FIG. 155.—Large Cast-iron Trépan.

of which are attached steel teeth weighing about 1 cwt. each, and so placed that as the bar is rotated round the central axis of the pit each tooth in falling

with the bar cuts for itself an annular portion of the bottom of the shaft; sometimes this tool is constructed of cast-steel, as shown in Figs. 154 and 155. The débris made in cutting out the central advance pit is removed by means of a grab (Fig. 137), or of a sludger (Fig. 156) attached to the rods, but that made in cutting out the shaft to its full size can be collected in a vessel of the kibble type placed in the advanced hole, and drawn to the surface when full (Fig. 157). A common size of engine is 39⅜ inches cylinder and 40 inches stroke. It is placed below the beam, so that admission of the steam above the piston raises the rods, which fall by their own weight and that of the trépan. The piston-rod of the engine is in direct connection with the beam, which is usually 23 feet long, 11 feet on the side of the borer and 12 feet on the side of the engine, and made of two logs of pine strengthened by a short iron plate, or, in more recent instances, a wrought-iron beam weighing about 9 tons has been used. The rods, which are usually of 8 inches square pitch pine, are in 20-yard[1] lengths, and connected up by "male" and "female" screws, and suspended to the beam by means of a strong flat chain (see Fig. 158). Intervening between the column of rods and the attachment

FIG. 156.—Sludger used in the Kind-Chaudron Process. (From Lupton's *Mining*.)

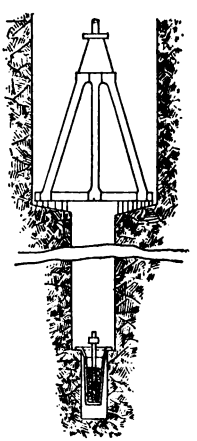
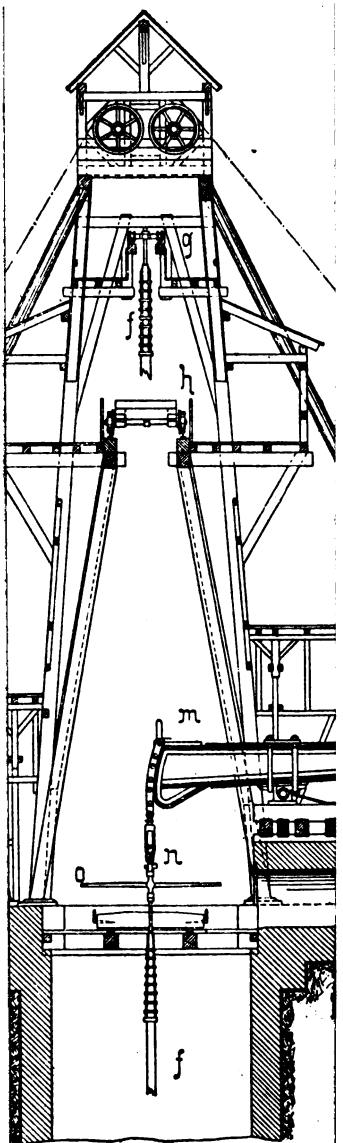


FIG. 157. — Kind-Chaudron Sinking, with three sizes of Boreholes. (From Lupton's *Mining*.)

[1] The boring rods, which were formerly 16 metres long, have been recently increased to 20 metres.

to the beam is a lengthening screw, below which is a strong swivel by means of which a rotating movement is imparted to the rods and cutter. The length of stroke of the rods varies between 10 and 24 inches, and the number of strokes from 9 to 20 per minute. The cutters or trépans are about 9 feet high, and their weight, of course, depends upon the diameter of the shaft to be sunk. Those shown in Figs. 154 and 155, which are the design introduced by Messrs. Haniel & Lueg of Düsseldorf, weigh respectively 12 and 25 tons, the former being the small borer used for making the advance hole, and is 8½ inches wide. The teeth, it will be observed, are so formed that they cut a sloping bottom, so as to allow of the fragments rolling into the centre of the shaft, which permits of the more easy extraction of the débris. The large cutter is guided by a cradle carried below, as shown (Fig. 155), which fits loosely into the advance shaft, or the cutter itself is surrounded with a circular cylindrical guide fitting into the large shaft itself. When it is desired to remove a trépan with a view to substituting for it another tool, or to sludge out the shaft, the surface arrangements allow of this being done most expeditiously —each length of rod is unscrewed and wound up by a hempen rope, worked by the winding engine (*i*) (Fig. 158), to the staging (*g*), where it is caught by a trolley and rolled away. It will be seen from Fig. 159 that there are two such stages, one carrying the rods and a lower one the trépan. The time occupied in raising and unscrewing and removing 1150 feet of rods (about 15 lengths), as well as removing the trépan, was, in the recent sinking at the Dover Colliery, not much more than one hour.

The progress in sinking varies, of course, with the



Process. Arrangement for Work

s. (*l*) Hand-controlled Steam
g Lengthening Screw. (*o*) Le

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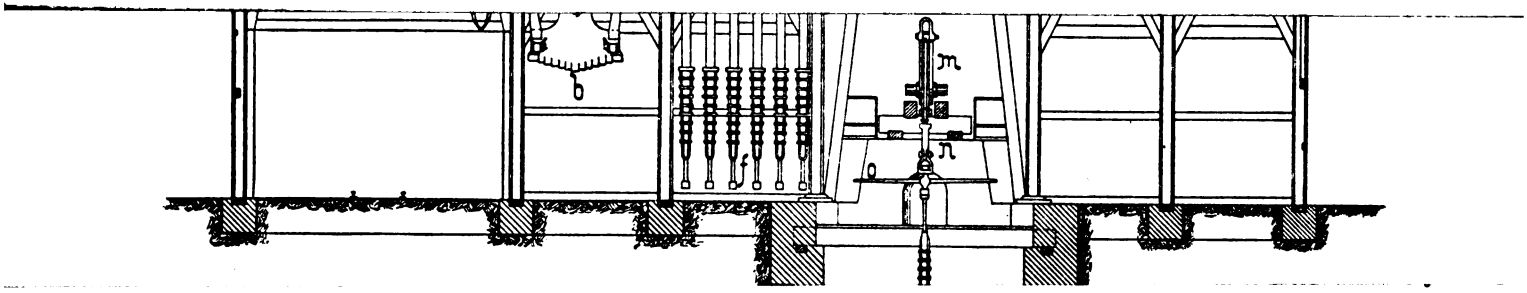
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character of the strata sunk through; 3·28 feet *per diem* is not an unusual rate through rock of moderate hardness, but in hard rock the rate will be about a quarter of this; the average rate of sinking through the Cretaceous beds at Dover Colliery in 1903 was 1 foot 3 inches *per diem*. The large cutter will advance at about $2\frac{1}{2}$ times the rate of the smaller one.

Inserting the Tubbing.—The most remarkable part of the process is perhaps the operation of inserting and fixing the tubbing without the use of drainage appliances to empty the shaft. Having sunk the shaft some distance below the water-bearing rock, and all possible care having been taken to secure a firm and level bed for the tubbing to rest upon, it is lowered into the shaft, a water-tight joint being secured in the following manner:—The bottom flange (A) (Fig. 160) of the lowest ring of tubbing which comes to rest on the water-tight rock is turned outwards, and its top flange (B) inward, round the exterior, moss packing is held in position by a net placed at the back of the ring of tubbing, and springs (DD) are so arranged as to force the moss against the sides. Above this, and resting on the moss, is another ring, the bottom flange (E) of which is turned outwards, and is of such a width as to allow of its sliding behind the lowest ring guided by the rods (H). Fig. 161 is a view of a moss-box completely erected. When the moss has been pressed down by the weight of the superincumbent column of tubbing, other rings, each 5 feet in

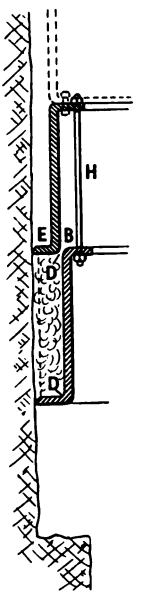

FIG. 160.—Section of part of the Moss-Box and Bottom Ring of Tubbing, showing Arrangement of Flanges.

length, are erected at the surface. The lowest rings

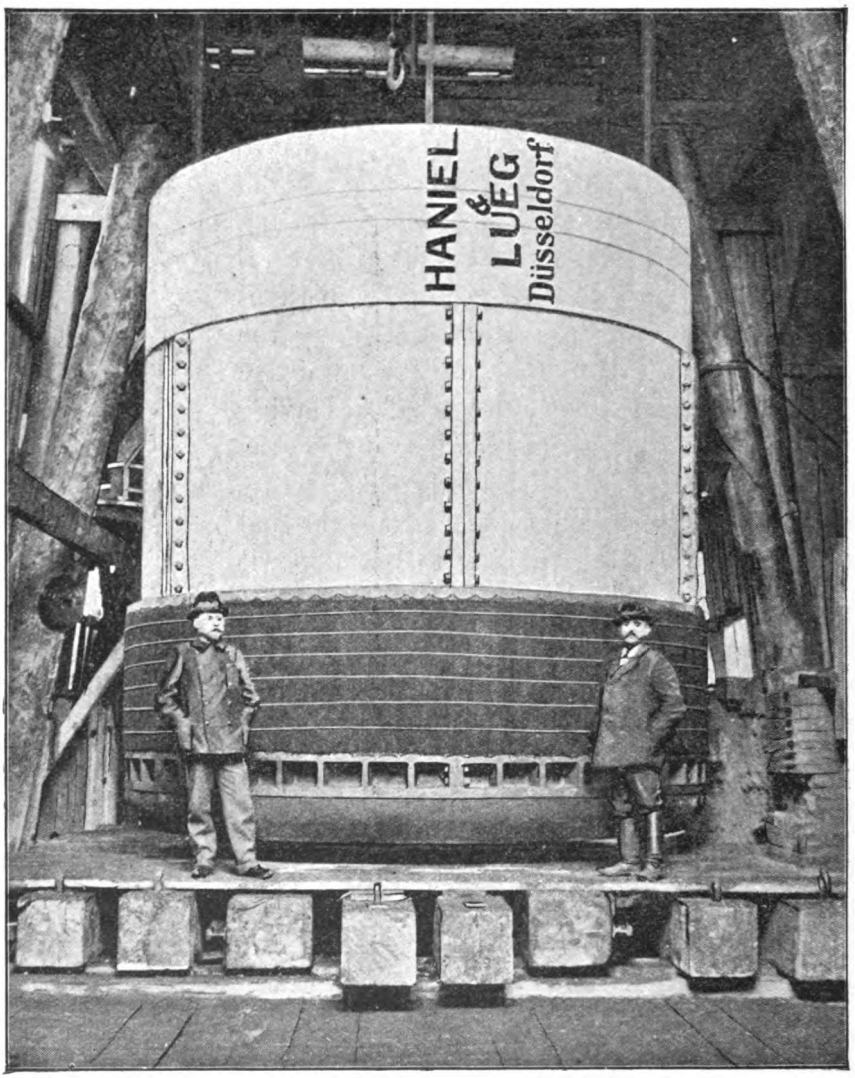

FIG. 161.—Moss-Box.

of tubbing are the thickest and heaviest, those above being gradually reduced in strength, as they have to

withstand a less external pressure and dead-weight. For instance, in the recent sinking at Dover, the lowest rings of tubbing weighed about $16\frac{1}{2}$ tons each, and in the upper series about $7\frac{1}{2}$ tons each; and the rings were subjected to a test by hydraulic pressure of from 45 atmospheres in the case of the first series, and of 10 atmospheres for the upper rings, before being put in.

To assist the lowering of the great weight of the column of rings of tubbing, a false bottom (*a*) (Fig. 162) is attached by screw bolts near the bottom of the tubbing, from which is carried a central or equilibrium tube (*b*), in which cocks are placed at intervals to allow of water being let into the middle and so assist its descent. By this means, in one case, 800 tons weight of tubbing was reduced to a weight of 40 tons resting on the suspension rods. Under the older arrangement it was necessary to use six winches and six very long and costly rods for lowering the tubbing (see Fig. 163), but Mr. Chastelain, the chief engineer to the Kind-Chaudron Company, devised a hook by means of which the tubbing can be lowered with the same rods and appliances as are used in the boring operations. The descent of the tubbing can be guided in the manner shown in Fig. 162. When all the tubbing has been lowered, the water is

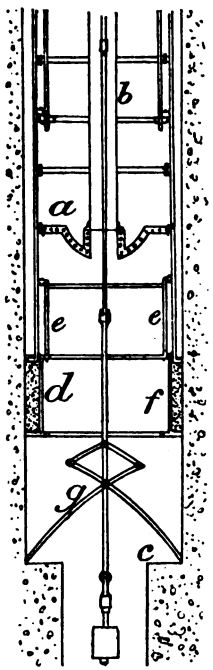

FIG. 162.—Mode of Tubbing the Dahlbusch Pit, Westphalia. (From Lupton's *Mining*.) (*a*) False Bottom; (*b*) Internal Tube for drawing out the water on completion of Tubbing; (*c*) Bed for Moss-box; (*d*) Moss-box; (*e*, *e*) Bolts; (*f*) Second Ring packed with Dried Moss; (*g*) Forked Tool for scraping Bed.

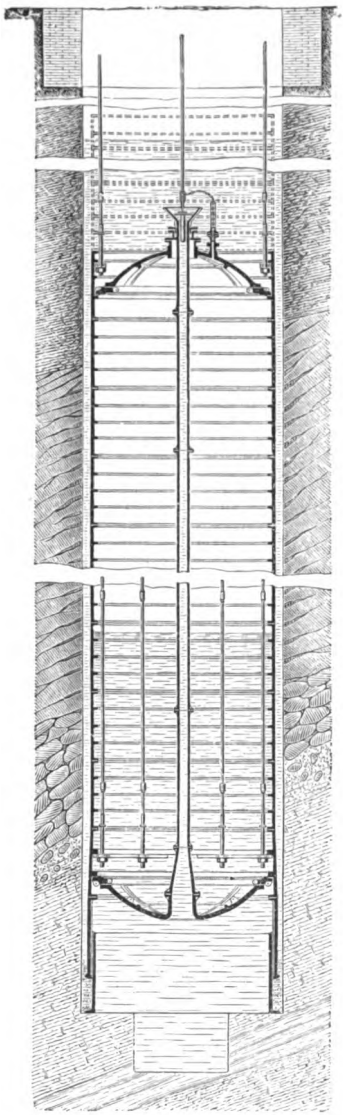

FIG. 163. — Kind-Chaudron Mode of Tubbing a Shaft, showing False Bottom, Equilibrium Tube, Lowering-rods, &c.

pumped out of the shaft, the false bottom removed, and concrete, composed of hydraulic-lime and sand, lowered behind the tubbing by means of special boxes so designed that they can be discharged when they have reached the required position.

It is generally found desirable to underset the moss-box by one or more wedging curbs and a length or two of tubbing in order to make the former quite secure. Sinking can then be resumed by ordinary methods.

Method of Boring and Thickness of the Tubbing.—The rings of the tubbing, having carefully tooled edges, are set on sheet lead $\frac{1}{10}$ inch thick, and bolted together, there being between the bolt head and the nut on each side of the flange a washer of lead which ensures a tight fit (see Fig. 99).

The formula used by Herr Reimer for calculating the thickness of the metal in tubbing is—

$$e = \frac{R \times P}{S}$$

where R = the external radius of the tubbing,
P = the pressure it has to withstand,
S = the resistance to crushing of cast-iron, or 800 kilogs. per square centimetre.

Giving these letters the values below, viz.—

$$e = (220 \times 40) \div 800$$

he finds that the tubbing must be 11 cm. thick. Now, as 11 to 12·5 cm. is about the limit at which the rings of tubbing can still be made reliably staunch, and by reason of their weight be considered reasonably portable, and as cast-iron and cast-steel have about the same value in respect of compressive strength, it will become necessary, in the case of shafts sunk to great depth by the Kind-Chaudron process, to reduce the diameter of the shaft (*i.e.* of the rings of tubbing), or resort to lighter tubbing, using two rings instead of one, and inserting concrete or cement in the annular space formed between them.

The Advantages and Applicability of the Kind-Chaudron System.—The advantages of the system may be epitomised as follows:—

1. A very hazardous operation is converted into one of comparative certainty.

2. The sides of the shaft stand during boring because of the pressure against them of the water inside the shaft.

3. An economy of from 50 to 75 per cent. has been effected in the outlay as compared with ordinary systems carried out in the same districts, which great gain arises mainly from the fact—

(*a*) That no pumps are used.
(*b*) Eruptions of quicksand are in a great measure prevented.
(*c*) A comparatively small number of men is employed, and for the most part those employed are less highly paid than regular sinkers.
(*d*) As there are no vertical joints in the tubbing, there is less leakage of water, less wedging to be done, and less tendency to displacement of the tubbing.

4. Risk to life is to a great extent eliminated, as practically the whole of the work is done from the surface.

5. As water is not pumped during the operation of sinking, damage to buildings and wells in the neighbourhood is avoided.

It will be seen that the Kind-Chaudron is more suitable for sinking through fairly firm, heavily water-bearing rocks than through overlying surface-deposits, to which the piling, caisson-sinking, or freezing processes are more adaptable. A depth of 200 yards has been reached by the Kind-Chaudron method.

Results.—Comparative costs constitute very unreliable data from which to draw conclusions, but from the accounts of the sinking of the new shaft of the Royal Wurtemburg Friedrickshall Salt Works, near Kochendorf,[1] one is able to glean facts of considerable importance. So great was the influx of water at the shaft—at one time estimated at 8900 gallons per minute—that it was determined to adopt the Kind-Chaudron process, in order to get through that part of the strata which was most heavily watered. From May 3, 1888, to June 30 of the same year, 24·5 metres were bored. Putting in the cylinders of tubbing, making the same tight, unwatering the shaft, sinking by hand below the moss-box, and undersetting the same with tubbing, occupied until February 15, 1899; the cost of boring out 24·5 metres, and lining 31·4 metres with tubbing, amounting to £17,131, 14s. 10d. (the shaft was 17 feet in diameter). Allowing for the sale for superfluous plant, and calculating on the 31·4 metres of shaft, equal to 34⅓ yards, the cost works out at £437 per yard of shaft sunk, and the rate of progress, reckoning as from December 6, 1897 (when hand-sinking was abandoned, and preparations commenced for the Kind-Chaudron

[1] *Shaft-sinking in Difficult Cases*, by J. Reimer, translation by J. W. Brough, pp. 31–35.

process), to February 15, 1899, averaged 7·28 feet per month. These apparently unfavourable figures acquire a different aspect when compared with the cost and progress during sinking with pumps. The depth from 302 feet to 331 feet sunk from October 9, 1896, to December 6, 1897—that is, 29 feet—also occupied fourteen months, and represents a monthly progress of 25½ inches, the cost being £1563 per yard. The cost of this system of sinking shafts may be said to vary, as a rule, from £12 to £57 per foot sunk.

The following synopsis of the cost of sinking No. 2 pit at Gneisenau Colliery, near Dortmund, is taken from "Novelties and Progress in Sinking in Loose Ground," by M. H. Lueg, of Dortmund, published in the *Zeitschrift für das Berg-, Hütten- und Salien-Wesen*, vol. xxxv., *Abhandlungen*, page 1, and is valuable as differentiating the chief items in an extensive undertaking of this sort.

1. Sinking through alluvium and upper marls down to 82 feet, including 52½ feet of brick walling and 29½ feet in cast-iron tubbing—		
(*a*) Winding, clay and sand, carriage, sinking in marls to 82 feet, drainage, supervision, and technical charges . . .	£909	
(*b*) Materials for walling and tubbing, and cost of building and erection . . .	1769	
	——	£2,678
2. Sinking through fissured marl, with cast-iron tubbing, 82 feet to 200 feet—		
(*a*) Sinking cost (items as above) . .	£1485	
(*b*) Tubbing, inclusive of erection . .	2227	
	——	3,712
3. Sinking and walling in compact marl, 200 feet to 656 feet		4,488
Total cost to 656 feet . .		£10,878

4. Boring from 656 to 800 feet, and tubbing 587 feet to 800 feet—			
(*a*) Preliminary to boring			£255
(*b*) 6½ feet bore, 656 to 803 feet		£815	
(*c*) 14¾ feet bore, 656 to 800 feet		1368	
(*d*) Tubbing—			
Various materials	£348		
Tubbing rings	3665		
Moss-box	274		
Bolts and screws	211		
Wages	466		
		4964	
Closing curb		48	
(*e*) Supervision and technical remuneration		1149	
(*f*) Concreting—			
Materials	£440		
Wages	98		
		538	
			8,882
5. Depreciation of temporary appliances, boring machinery, tools, &c.—			
Boring frame and foundations		£525	
Engine and boiler		248	
Various tools		2065	
			2,838
			£11,975
Total for bored portion of shaft			£11,975
Total entire sinking			22,845

The cost, therefore, from the surface to the first of the tubbing, was at the rate of £28, 10s. per foot; but if the old plan of tubbing had been followed, the cost would have been about £7500 more, or at the rate of £39 per foot.

It was estimated that a saving of no less than £10,240 was effected by adopting the Kind-Chaudron system of sinking instead of hand-sinking and pumping.

The boring between 606 and 800 feet, and the tubbing up to 587 feet, were finished in about a year—which, it was estimated, was the time which would have

been occupied had hand-sinking been resorted to—inclusive of five and a half months' building of the engine (seven and a half months' sinking).

In the tabular statement given by Herr Reimer in his valuable work on sinking already alluded to, only five shafts are mentioned as having been sunk in England by the Kind-Chaudron process, but the five shafts are representative of only three collieries. The method was first applied in this country, and then unsuccessfully, at Cannock and Huntingdon Colliery, in Staffordshire, in 1876, to sink through the water-bearing red rocks of the Permian system; and shortly after at Whitburn Colliery, to sink through the heavily watered magnesian limestone and underlying yellow sandstone (Middle and Lower Permian); and as recently as 1903 at Dover, to sink through the Cretaceous rocks.

The following memorandum[1] on the Whitburn Winning is of interest as showing the succession of events which led up to and rendered necessary the adoption of the Kind-Chaudron method of sinking and lining the shafts at the Whitburn Colliery.

On July 12, 1873, a bore-hole was commenced on the Hope House estate, about . . . yards east of the farmhouse, to prove the thickness of the limestone and depth to water.

This hole was put down 15 fathoms, when, owing to the difficulties encountered by loose strata above falling into the hole, and fixing bore-rods, it was determined to stop the bore-hole and sink a small staple down on the top of the same; this was commenced on . . . and finished down to level of water on . . ., 15 fathoms from surface; commenced boring again in staple bottom and proved thickness of limestone.

[1] Taken from MS. in the possession of the author.

The site of the pits was then determined on about . . . yards north-east of the farmhouse, and operations were commenced to clear away the hillside as a base of operations.

Commenced to sink No. 1 shaft, 15 feet finished diameter, December 23, 1874, with a few men and one shift per day until sinking-engine was ready.

This was a 25 H.P. Robey engine, with boiler and two drums complete, fixed on a temporary brick foundation and placed so as to work into both Nos. 1 and 2 pits; also staple No. 1 pit was sunk to water, which was reached at 18½ fathoms, and then walled up and completed to surface. This was stopped and staple was commenced with January 2, 1875, and sunk down to the water, walled up, and completed to the surface.

Commenced then to build the pillars for the large pumping quadrants, and foundations for pumping-engine, boilers, &c.

July 5, 1875, commenced to put first set of 20-inch pumps into No. 1 pit. July 30, commenced pumping, and sunk pit down, with water increasing, to 25 fathoms 5 feet, where a heavy feeder was met with on September 7, engine going at 18 strokes per minute—1440 gallons.

Continued pumping until September 14, when it was determined to put in 20-inch set, drive the drift over to staple, and sink staple down 12 feet, and put in a water-tight bottom.

The second pit had by this time been put down to water-level, which was 14 feet diameter finished; the drift was also driven to it. November 13, commenced engine again with two 20-inch sets, and continued to November 20, when we stopped, as engine could not keep the water down (pumping 3200 gallons per minute).

Seeing now that the quantity of water likely to be

met with was a very serious question, and much in excess of expectation (for the engine-power applied), and after repeated consultation, it was decided to apply all the pumping power possible, which was as follows:—

To take out the 20-inch sets in pit, and put two 30-inch sets in their place, to deliver through drift into staple bottom.

These two 30-inch sets to be put in staple, to lift from the two low sets to surface, and worked by a pair of 48-inch cylinder engines, 6-feet stroke.

To put a 20-inch set into pit, and lift to a 20-inch standing set to surface; to work these a 100 H.P. marine engine was applied, with spur-gear 3 to 1. On the second pit a pair of 24-inch cylinder, 4-feet stroke engines was put down and applied, with spur-gear 3 to 1, and two 20-inch sets put in pit to lift to surface.

Permanent chimney and flues were then built, and eleven more boilers put down to the size already erected; this was completed, and pumping at No 2 pit commenced, March 8, 1876, and put same down nearly to the same level as No. 1 pit, when water came through, June 8.

All engines were then put to full speed to keep water down, and to try to pump it off until July 1, 1876, when all works were stopped, all engines going at the following speeds:—

No. 1 Pit.

	Quantity of water pumped.
Two 30-inch sets, 6-feet stroke, 18 strokes per minute .	6,580 galls.
One 20-inch set, 5-feet stroke, 24 strokes per minute .	1,608 „
	8,196 galls.

No. 2 Pit.

Two 20-inch sets, 5-feet stroke, 24 strokes per minute .	3,216 galls.
Total	11,412 galls.

The diagrammatic section of No. 2 shaft (Fig. 164), showing the position of the gullets, and giving details as to the composition of the concrete at the different heights, is of interest.

According to M. Chaudron,[1] the most difficult undertaking that has been entrusted to him since his system of sinking has been in use, was that of putting down a shaft at the Nord du Flènu Collieries at Ghlin, where the following strata had to be penetrated—

Sandy clay, sand, and gravel	59·05 feet
Mons limestone, firm	19·68 ,,
Chalk, green-sands, and blue clay of the Upper Chalk Quicksands and gravel with clay intercalated	880·92 ,,
especially near the bottom	47·57 ,,
	1007·22 feet

The sinking comprised two distinct operations, viz.—

(*a*) Sinking down to 958 feet with the shaft full of water.

(*b*) Sinking through the quicksand into the Coal-Measures, which occurred at a depth of 1063 feet, where a bottom for the tubbing was found. Telescopic sheet-iron cylinders were used to prevent the inrush of the sand, five columns being used to line the lower 125 feet.

The commencement of operations was made in May 1873, No. 1 pit being finished in 1886, and No. 2 in 1887.

The following items of cost are interesting :—

Total weight of tubbing, 5000 tons at 20s. to 21s. 6d. per ton.
Total cost of sinking, £161,080, or an average of £78 per foot.

Sinking Shafts by Hydraulic Shock Boring.—The problem of boring shafts by hydraulic shock trans-

[1] "The Mining Industry of Belgium," by A. Briart, *Trans. Inst. M.E.*, vol. xv. pp. 470–490.

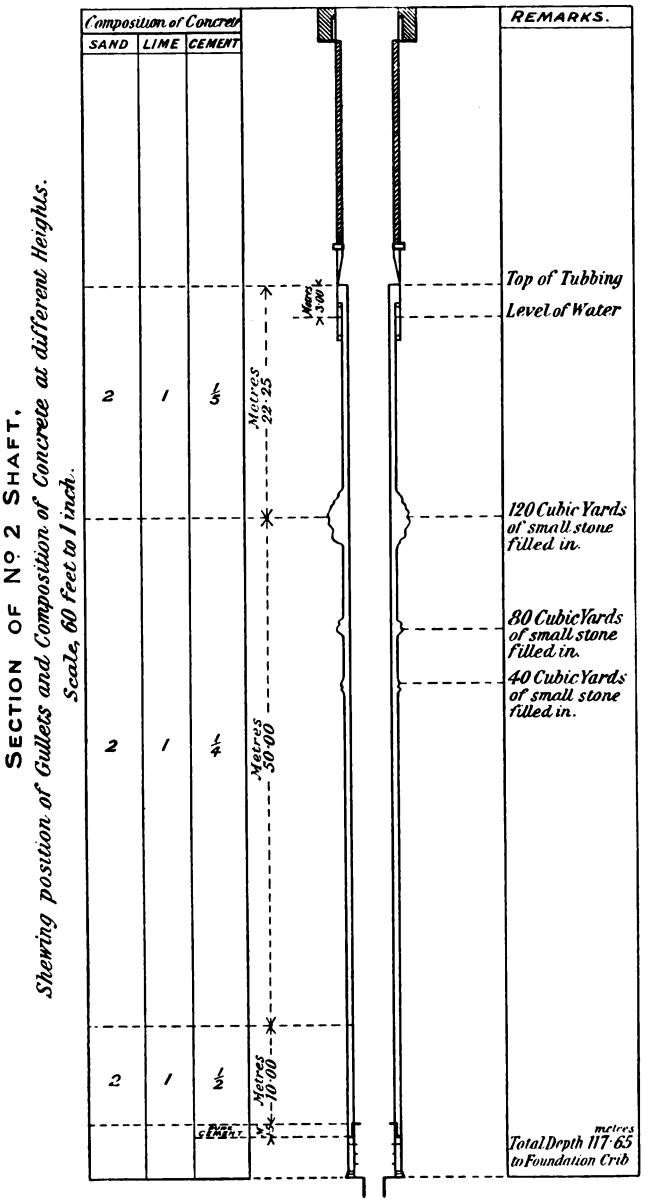

FIG. 164.—Section of a part of No. 2 Shaft, Whitburn Colliery.

mitted to cutters stationed at the bottom of the hole, which is the latest development in shaft-sinking, would appear to have been solved by the Deutsche-Tiefbohr-Aktiengesellschaft, of Nordhausen, in the use to which they have put the Wolski hydraulic boring-ram. Special features of the apparatus are the valve, which governs all the boring bits at once, the manner in which the outer bits are mounted at an angle to diminish the wear on the lateral cutting edges, and the method of flushing up the mud from the bottom of the shaft by the wash water from the boring tool.

In Fig. 165 (*a*) represents the bits, of which there are six, arranged in a circular casing, each 16 inches in diameter, (*b*) is a guiding shoe fixed to the bottom (*g*) of the apparatus—the shoe also forms the nozzle (*c*) of the water flush, (*p*) is an extension of the cylindrical casing, which acts as a protecting shoe to the bits when the apparatus is being lowered on to the bottom of the shaft, (*d*) is a retractive spring with which each bit is provided, abutting against a removable sleeve (*e*), which is attached to the bit shoe by a strong tapered bolt (*f*). The pipes (*h*) both guide the springs and stay the bottoms (*gg*), being bolted at the bottom on to the bit shoe and at the top to the distributing arm (*i*), into which arm are tightly screwed the hardened steel cylinders (*k*). The pistons (*n*) operating the piston-rods (*o*) are worked by the pressure water from the head (*l*), passing through the conduit (*m*). The common governing valve (*q*) is situated in the lower part of the head (*l*), at the top of which is the connection (*r*) leading to the hammer pipe (*s*). The cylinder (*u*) is a mud tank mounted on the apparatus. The hammer pipe, which is 50–65 feet long, is connected to a wind chest of specially designed type, and this again is connected

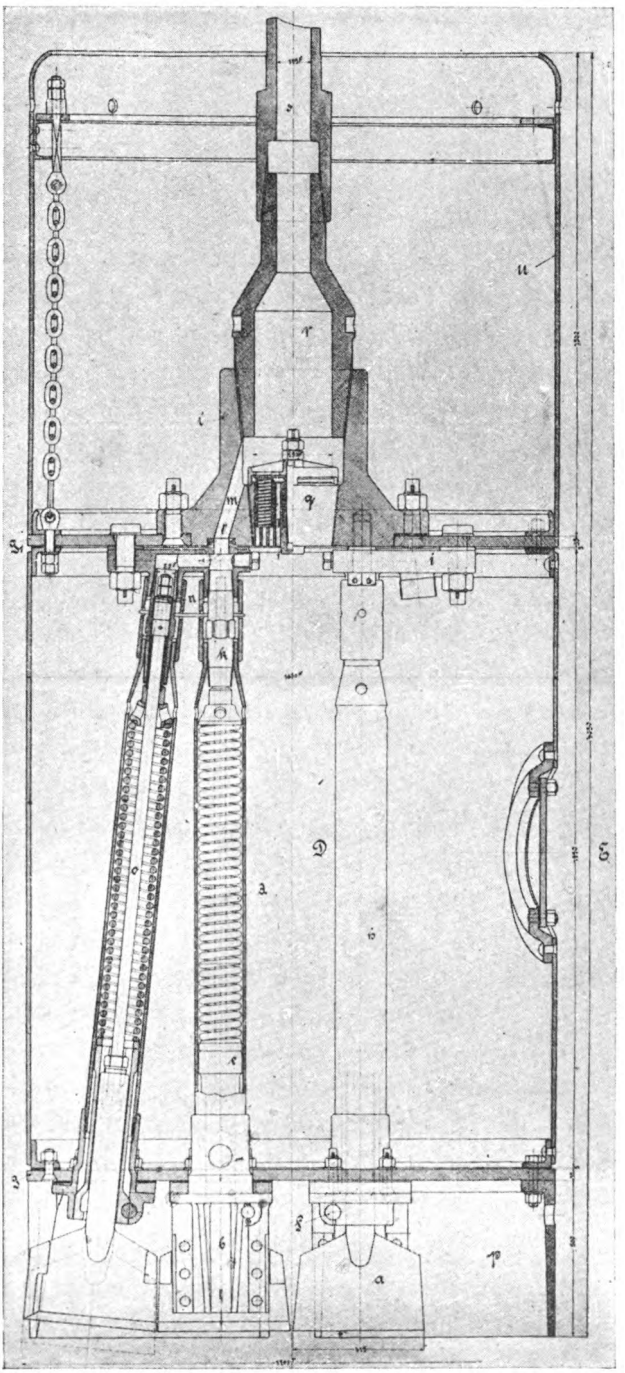

FIG. 165.—Shaft-boring Apparatus, worked by Hydraulic Shock.

to the hollow rods. Herr Frieh, the engineer to the Deutsche-Tiefbohr-Aktiengesellschaft, thus describes the method of working:[1]—

"Water under a pressure of thirty atmospheres is forced into the hollow rods, passing thence through the wind chest, 'hammer pipe,' and open valve. As soon as the flow reaches a certain velocity, the valve is forced to, and the resulting water 'hammer' drives the pistons and bits against the bottom of the shaft. The water 'hammer,' however, lasts only a short time, depending on the length of the 'hammer pipe'; and as soon as this period has lapsed, the column of water in the 'hammer pipe' rebounds, from the valve and pistons, in the direction of the wind chest, thus enabling the springs on the valve and bits to expand and set the apparatus ready for the next stroke. The waste water from the bits passes inside the apparatus and escapes through the orifices in the bit shoe on to the shaft bottom, where it flushes the débris through the narrow space between the shaft walls and the apparatus up to the mud tank," the latter being cleaned out when the boring tool is raised to the surface. Herr Frieh adds, "The rate of boring through sandstone with this experimental plant in the first trials—which, of course, could not afford any criterion of the maximum efficiency—was two-fifths of an inch per minute of actual working time."

Herr Frieh expresses the opinion that there are no special technical difficulties in the way of constructing a plant of this kind for boring shafts "of the usual 16 feet diameter," and that it "seems probable that the apparatus is destined not only to inaugurate a new

[1] "The New Shaft-boring Apparatus of the Deutsche-Tiefbohr-Aktiengesellschaft." Paper read before the International Mining Congress at the Liége Exhibition, June 26, 1905, by E. Frieh.

era in shaft-boring, but also to supersede the ofttimes dangerous operation of sinking by hand."

The present writer is not aware whether this apparatus has yet been used in actual practice. If so, it would be interesting to learn what results have attended its application. It has been claimed for it that it will overcome many of the difficulties and drawbacks inherent in the older and well-tried methods. For instance, the great loss of power that occurs in its transference through the rods to the boring tool, characteristic of all other boring methods, would be overcome, as well as the loss of time necessitated by the frequent drawing of the rods. The automatic clearing of the hole is also, it is claimed, an advance on many of the older boring methods. Loss from breakage of rods, fishing out of lost tools, &c., will also be obviated.

The Cementation Process.—The process consists in forcing liquid cement, by means of compressed air, steam, or water, under pressure into the ground to be sunk through and thereby consolidating it. In injecting cement behind tubbing it was found that more cement was used than was warranted by the volume of the space between the tubbing and the sides of shafts, and it was presumed, therefore, that by forcing cement into loose ground or fissured rocks until no more would penetrate, a consolidated and water-tight zone of sufficient extension might be found to enable sinking by ordinary means to be proceeded with.

The method was tried for the first time in 1904 in sinking the No. 11 shaft of the Béthune Colliery, in the Pas-de-Calais, through the Cretaceous beds, where the procedure was as follows:[1]—

[1] "Cementation des Terrains aquifères en Vue de Creusement des Puits," by H. Portier, *Congrès International des Mines, de la Métallurgie, de la Mécanique*

The finished diameter of the shaft was 5·2 metres (17·06 feet), within the area of which four holes were put down for the injection of the cement, the holes being bored on two diameters crossing at right angles, and about 12 centimetres (5 inches) inside the perimeter of the future shaft. The water-tightness of the upper part of the measures was ensured by boring a hole 500 mm. (19·68 inches) in diameter to a depth of 13·05 metres (42·81 feet), the upper part of which was tubed, continuing it at 300 mm. (11·81 inches) in diameter to a depth of 37·75 metres (123·85 feet). Tubing 14·2 metres (46·59 feet) long having been inserted at the top of the hole, the annular space between the two tubes was filled with a mixture of sand and cement. The water-level not having been reached, it was found necessary to damp the ground to prevent the water in the liquid cement being absorbed by the chalk and so leave a cement plug in the hole. To this end 24 cubic metres (5280 gallons) of water were first sent down, then followed by the injection of the liquid cement, the mixture at first being in the ratio of one part by volume of cement to ten of water, but the amount of cement was gradually diminished as the absorption decreased, until the ratio was one of cement to twenty of water, the liquid being forced down by pumping. When the liquid cement rose and returned to the surface tank, the tubing was flushed with water, then taken out, and the hole deepened.

It was found that the cement penetrated and set well in the more important fissures, especially if vertical, but not so well in the narrower (especially if horizontal) fissures, where it sometimes remained in a pasty con-

et de la Géologie appliquées, Liége, 25 Juin et 1 Juillet 1905: "Section des Mines," vol. i. pp. 419–439.

dition. The best way of extracting the mud from these fissures was found to be by means of pumping from the bore-hole. It is questionable how far the process, which is economical both in respect of time and money, can be applied to penetrating all classes of loose or water-bearing ground. But the success in the above instance points to its effective application in respect of fairly compact rock, such as chalk, which is traversed by numerous fissures containing water.

The Congelation Process.—The freezing of ground to enable shafts to be sunk through wet friable strata, in which, in many cases, sinking by ordinary means or by boring is either impracticable, slow, or carried out at great expense, was invented in 1883 by Poetsch, but the process in a modified form had been tried in Wales as far back as 1862. As now practised, however, it is not necessarily restricted in its application to running sands, but can be, and is, used to freeze strata, loose or otherwise, containing water in large quantities; though there can be no doubt that it would be more efficacious to bore out the shafts, than to freeze prior to sinking, where the ground to be penetrated is sufficiently firm to allow of it.

The congelation system is peculiarly applicable in the case of a friable bed surcharged with water occurring at some depth from the surface and below, say, a hard stratum, as in the case of the yellow (Lower Permian) sands below the magnesian limestone on the east coast of the Durham coalfield. The process has hitherto been confined to moderate depths for two reasons—(1) the difficulty of maintaining the verticality of the bore-holes if put down to considerable depths (see Fig. 169), and so ensure an efficient wall of frost, and (2) the plasticity of ice—"A wall of pure ice," says Herr Reimer, "would at

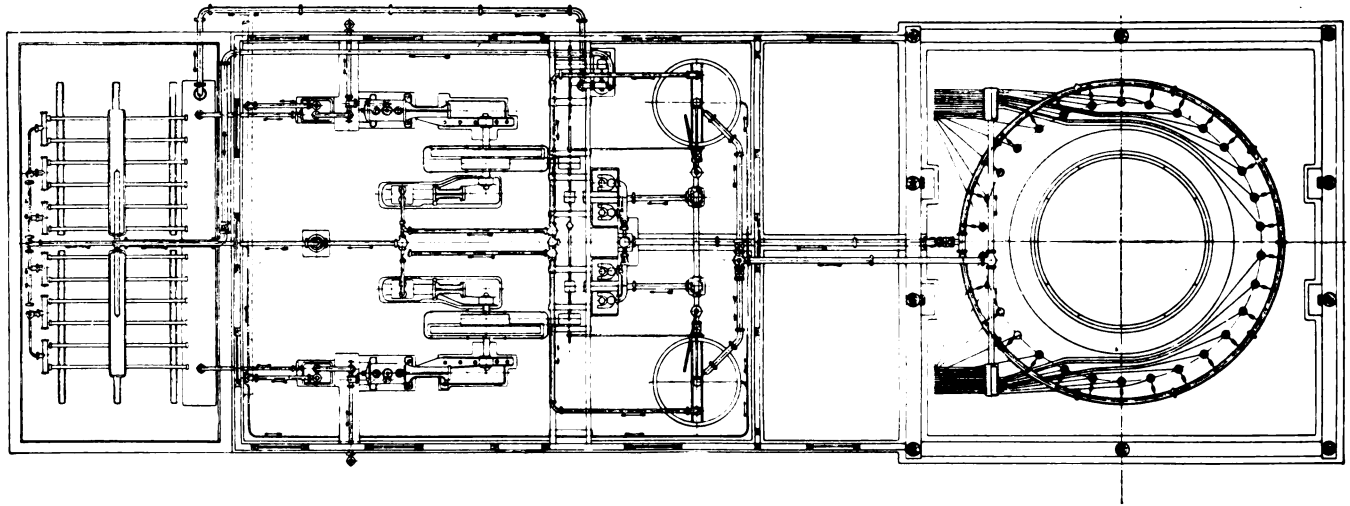

FIG. 166.—Ground Plan of a Freezing Plant.

a depth of 200 yards be as plastic as clay, and not capable of remaining standing"; the frozen wall, however, not consisting of ice alone, but of a mixture of ice, sand, and clay, the internal friction is much greater. The deepest shaft sunk by the freezing method is, according to Herr Reimer, that of the Schieferkante Company, which was evidently in process of being put down when he wrote his book, as he says it "may have to be frozen to a depth of 240 yards."[1]

One source of difficulty which has not been entirely overcome by this process is encountered when sinking the shafts through ground in which occur feeders of saline water, the brine requiring exceedingly low temperatures for its congelation.

The freezing liquid used is generally a solution of chloride of calcium or chloride of magnesium refrigerated by an ammonia plant.

In the Carré machine for generating cold, anhydrous ammonia gas is liquefied by compression in specially designed pumps, and the liquid, which leaves the compressing plant at a temperature of about 102° F. (38° C.), is cooled by passing it through pipes jacketed with cold water, and then into a series of long pipes laid in a tank containing the brine solution; expanding in these it reduces the temperature of the brine solution, the ammonia gas being conducted back to the compressor and re-compressed (see Figs. 166, 167).

In Fig. 168 is given a general view of the buildings on the site of a sinking by the congelation process.

In one case the plant consisted of two 75 to 80 horse-power steam-engines, each driving an ammonia compressor with a total output of 240,000 calories per hour. A 28 per cent. solution of chloride of calcium

[1] *Sinking in Difficult Cases*, p. 64.

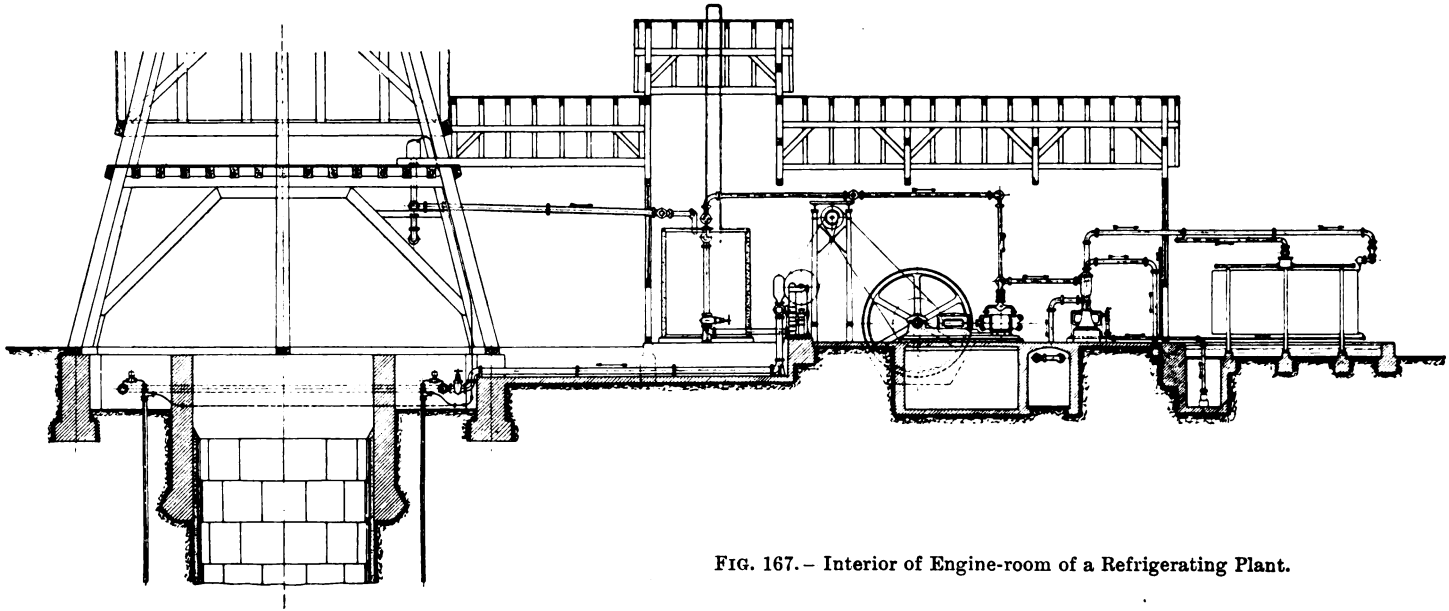

FIG. 167. – Interior of Engine-room of a Refrigerating Plant.

was used, and 8800 gallons of cooling water at a temperature of 10° C. were required per hour.

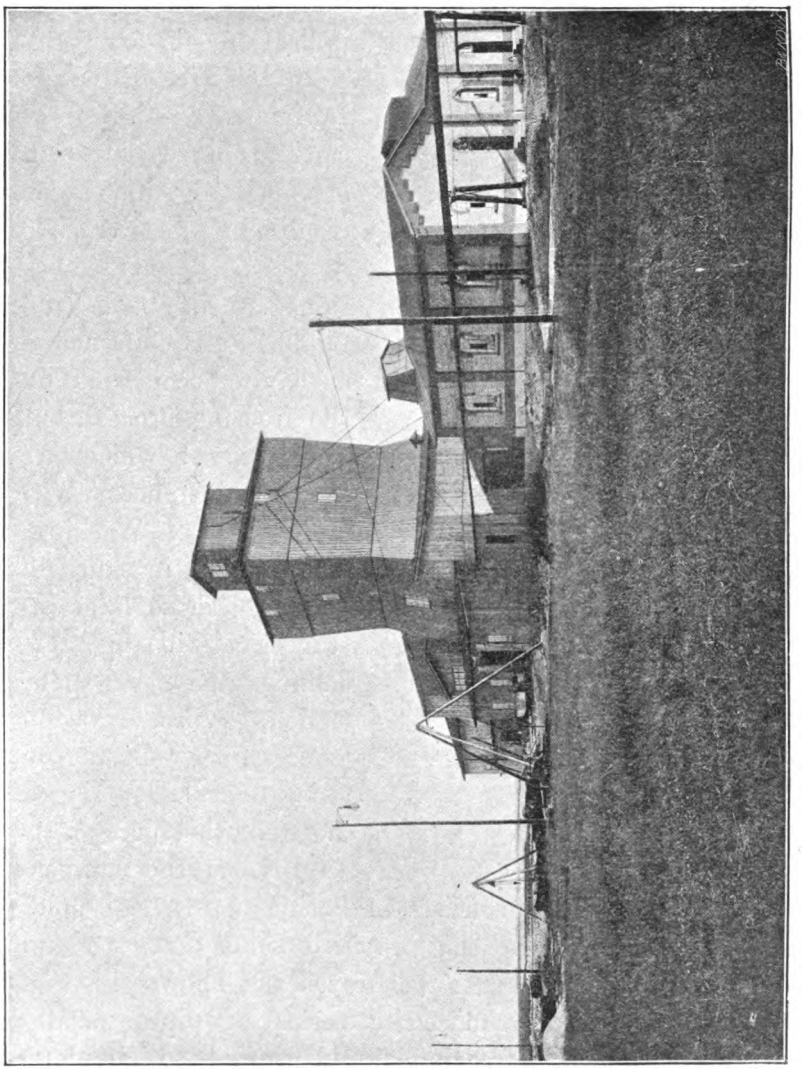

FIG. 168.—General Surface View of an Installation of a Freezing Plant.

Leakages [1] of the freezing solution through cracked

[1] See "Modern Methods in Shaft-sinking," article by the author in the Engineering Supplement of *The Times*, July 24, 1907.

pipes renders congelation of the beds more difficult, owing to the lower freezing-point of the watery stratum, due to the infiltration of the alkali; and efforts made in the direction of direct application of cold by evaporation of the ammonia gas in the freezing pipes instead of the circulation of refrigerated chloride of calcium, have not been attended by satisfactory results in practice.

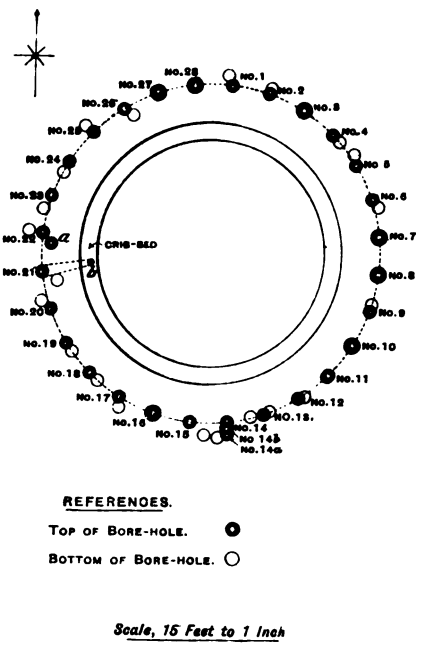

FIG. 169.—Position of Bore-holes at one of the Shafts at Dawdon Colliery, Durham.

Herr Reimer mentions in his book (pp. 90–93) sixty-four shafts as having been sunk by the freezing process, but only two of which are British instances, viz. two shafts at Washington Colliery in Durham (1901). Three later instances, all in the same county, may be mentioned, viz. Dawdon (successful), Easington (unsuccessful),[1] and Wearmouth (successful).

Briefly, the application of the process consists in boring a series of holes outside the circle of the proposed shaft down to and through the stratum to be frozen, as shown in Fig. 169,[2] in which are placed a series of pipes usually arranged, and the freezing liquid caused to circulate,

[1] The author understands, however, that the freezing process is being again, and successfully, resorted to at Easington.

[2] Reproduced from *Trans. Inst. M.E.*, vol. xxxii., by permission of the Council of the Institution.

in the manner diagrammatically explained in Figs. 170, 171.[1]

Two instances may be quoted, the one in which the strata to be frozen existed at the surface, the other in which it was overlaid by a considerable thickness of rock. At Washington Colliery[2] the freezing was undertaken by Messrs. Gebhardt & Koenig, of Nordhausen, Germany, who undertook to freeze two shafts to the stone-head. The strata to be passed through presented the following section :—

	Ft.	Ins.
Soil	1	3
Yellow sand, dry	34	6
Grey soil, wet	41	3
Blue clay	0	1
Grey sand with a gravel bed, damp	2	4
Clay with boulders, dry	12	11
Loamy clay, dry	5	2
Stiff clay with boulders, dry	9	7
Yellow freestone	13	0
	120	1

The refrigerating agent was ammonia, raised by compressors to a pressure of 150 lbs. per square inch; the strength of brine solution being 26 per cent. of chloride of calcium—a solution which freezes at 34° C. In this case the holes were bored inside the shaft area and the freezing tubes inserted as soon as they had attained the intended depth, the tubes being 4 inches in diameter and 16 feet long (see Fig. 172).

At Dawdon Colliery[3] (1903) two shafts were sunk 20

[1] Reproduced from *Trans. Inst. M.E.*, vol. xxxii., by permission of the Council of the Institution.

[2] "Sinking by the Freezing Method at Washington, County Durham," by Mark Ford, *Trans. Inst. M.E.*, vol. xxiv. p. 293.

[3] "Sinking through Magnesian Limestone and Yellow Sand by the Freezing Process at Dawdon Colliery, near Seaham Harbour, County Durham," by E. Seymour Wood, M.Inst.C.E., F.G.S., *Trans. Inst. M.E.*, vol. xxxii. pp. 551–577.

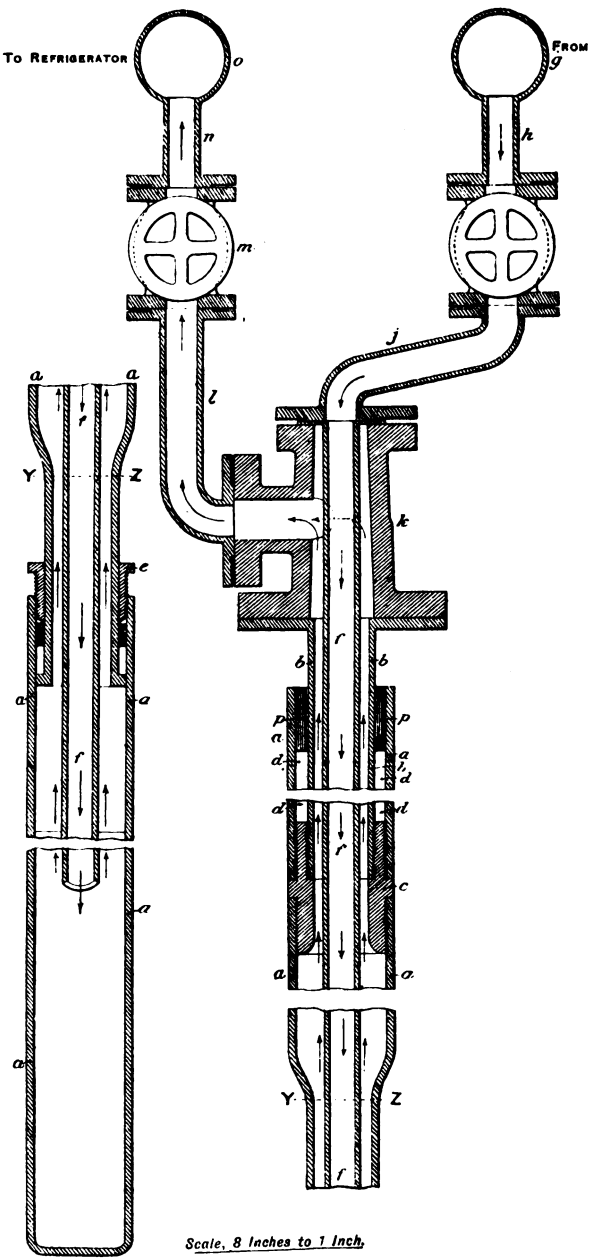

FIG. 170.—Section of Tube Arrangement for the Circulation of the Freezing Liquid at Dawdon Colliery, Durham.

feet in diameter, down to the respective depths of 350 and 204 feet, pumps being used to drain the water.

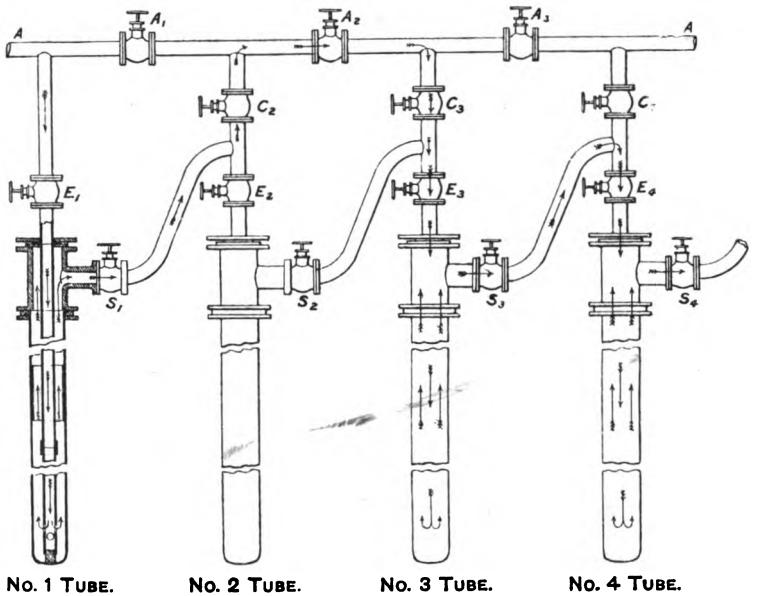

FIG. 171.—Arrangement of Tubes for Circulation of the Freezing Liquid, as applied at Dawdon Colliery.

Taking the section of the strata passed through at one of the shafts as illustrative of the geological conditions in that neighbourhood, there is—

			Ft.	Ins.
Recent and glacial		Soil	1	0
		Boulder clay	5	6
		Gravel	4	6
Permian	Middle	Magnesian limestone (Much water, 6075 gallons per minute largest feeder.)	356	10½
		Mark slate	3	1½
	Lower—Yellow sands		92	4

The work of freezing so as to allow of the shafts being farther sunk to a depth of 484 feet without the aid of

pumps was, in this instance also, undertaken by Messrs. Gebhardt & Koenig. The arrangement of the holes in the Castlereagh shaft is shown in Fig. 169. Twenty-

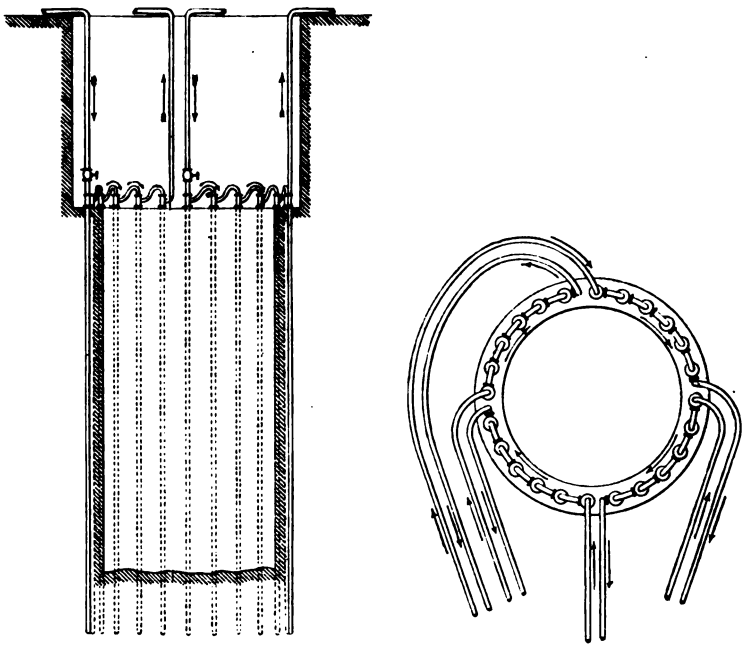

FIG. 172.—Arrangement of Freezing Tubes adopted at Washington Colliery, Durham.

eight holes were bored to 484 feet in twenty-four days, and they were lined with tubes as follows:—

Tubes	$9\frac{1}{2}$	inches diameter . . .	130 feet.
,,	$7\frac{1}{2}$	,, ,, . . .	330 ,,
,,	$6\frac{1}{4}$	,, ,, . . .	24 ,,

The brine solution contained 26 per cent. of chloride of magnesia reduced to a temperature of −17° C. (14° F.). The length of time required to form the ice wall was 185 days, and it was maintained for 353 days—that is, the total time of freezing was 538 days.

Cost of Sinking by the Freezing Process.—Early in the year 1894 arrangements were commenced to freeze the ground through which were to be sunk two pits belonging to the Auzin Collieries in the Scheldt Valley.[1] The process adopted was that of Herr Poetsch. The strata to be sunk through were sand, quartz, sandy clay, chalk, marl, clay, and green-sand of the Tertiary and Cretaceous systems; the depth to the Coal-Measures being 615·64 feet. The water contained in these beds is, down to a depth of 300 feet, very abundant. The Thiers pits had been previously sunk in the ordinary way and lined with 257 feet of tubbing, but the amount of water which had to be pumped was no less than 9000 gallons per minute, and the cost was £75 per foot, the sinking occupying a period of twenty-six months, hence the reason for adopting the congelation process in sinking the Vicq pits, as they are called. The diameters of these shafts were respectively 12 and 16·4 feet. The tubbing consisted of—

1st section,	20 rings	(100 feet)	1 inch thick.
2nd ,,	44 ,,	(205 ,,)	1·77 to 1·18 inch thick.
3rd ,,	15 ,,	(81 ,,)	1·97 inch thick.
		386 feet.	

The rings of tubbing were backed with concrete about 8 inches in thickness, in the making of which about 10 per cent. of chloride of calcium was mixed with the water to prevent it from freezing.

[1] "Fonçage des Puits de Vicq par le Procédé Poetsch," by Saclier and Waymel, *Bulletin de la Société de l'Industrie Mineral*, 1895, vol. ix. pp. 27–148.

The total cost of the sinking was as follows :—

	Per cent.	Total cost.	Per metre.
		Francs.	Francs.
Patentee's royalty	4·6	32,760·00	139·20
Temporary plant and buildings	2·7	19,582·40	83·25
Boring for freezing-tubes	10·4	73,673·03	313·10
Freezing plant	35·0	248,765·56	1057·20
Measuring apparatus	0·3	1,899·68	8·10
Freezing cost	4·7	33,030·95	140·40
Sinking and tubbing	40 5	287,454·77	1221·65
Carriage	0·6	4,562·00	19·40
Tools	0·7	5,257·00	22·35
Sundries	0·4	2,865·00	12·15
	99·9	709,850·39	3016·86

The freezing cost was made up as follows :—

	Francs.
Patent rights	32,760·00
Boring	73,673·03
Erecting	14,084·72
Measuring instruments	1,899·68
Freezing cost	32,030·95
	155,448·38

A summary of the expenses being—

	Cost per metre.	
	Francs.	Francs.
Material	234,680·84	1000·00
Freezing	155,448·38	666·00
Sinking	319,721·17	1360 00

APPENDIX

DURHAM DISTRICT (No. 4)

Sinking Pit Rules

Engineer

1. He, or some competent person appointed by the Manager, shall examine the state of the headgear, engines, boilers, and machinery, crabs, winches, ropes, and chains, with the several bolts, shackles, spring hooks, and all other tackle, at least once every day, and if found defective they are to be immediately put right.

2. He shall see that the boilers are cleaned as often as may be necessary, that the safety valves, feed valves, scum and mud taps, water and steam gauges, and all fittings are in good order.

3. He shall see that the top of and all side entrances into the shaft are properly fenced; and

4. Shall see that all sinking sets are carefully examined every twelve hours.

Master Sinker

1. He shall daily examine the state and condition of the shaft, ropes, chains, spring hooks, tubs, and all other things connected therewith; if anything is found faulty, or unsafe, shall report immediately to the Engineer, and stop sinking till remedied.

2. He shall not allow any person to ride on a full kibble, or on the edge of a kibble, but in all cases with one or both legs inside, and shall not allow more than the prescribed number of persons to ride at one time, such number to be fixed by the Manager and posted up on the pit top.

3. He, or some competent person, shall be present whenever

the crabs have to be either lowered or raised, and give all orders for moving them.

4. In every case where the three-quarter or smaller cradle is in use, and is stationary in the shaft, he shall have it properly secured to prevent it swinging, and shall see that the open sides are protected so as to prevent any one from falling off, and shall see that the chains, shackles, &c., are in good order.

5. He shall see that the cow is carried by hand at all times in front of the ground and cradle crabs when lowering, that each cradle or scaffold is so constructed with a grid or other contrivance as to allow of efficient ventilation underneath, and shall remove any gas which may be given off.

6. He shall not allow crabs to be lowered by hand when men are on the cradle, but shall keep a horse always in the crab when so used, or when the cradle is in the shaft, and at use, and shall see that the two halves of the cradle are securely bolted together when used for walling purposes, and that the flap over the tub hole is also securely fastened.

7. When necessary, he shall order the use of safety-lamps in the shaft or about the pit top.

8. He shall see that proper lamps or lights are provided on the surface during night time or dark weather.

9. He shall see that the proper hours of working and times for meals for boys under the age of sixteen years are attended to according to the Act.

Chargeman

1. One man in each shift shall have the entire charge and responsibility in the pit bottom, subject to orders from the Master Sinker.

2. He must go down in the first kibble and ride in the last in each shift.

3. He must see that all kibbles are reasonably and safely filled and stones properly packed, not above the level of the top of the kibble, and that the kibble is put into a proper line with the pulley before sending it away.

4. The kibble must at all times be carefully steadied, and the bottom kept free from stones and dirt. All gear or material must be put into an empty kibble, and if it project

above the level of the top, it shall be securely fastened to the bow before sending it away.

5. He shall change at the bottom, and after the work has been standing, or the men have been out of the shaft, shall examine the ventilation before they go down again.

6. He must in all cases be present at the firing of shots, and not allow any shots to be fired except under his direction, and shall see that the holes are properly placed and drilled, and must regulate the charges of the explosive.

7. After a shot has been fired he shall carefully examine the sides and canches, at and near the bottom of the shaft, and remove any loose stones.

8. He shall see that proper materials are used for stemming, coal or coal dust shall not be used, and a shot which has missed fire shall not be drilled out.

9. Where electrical firing is in use he shall have entire charge of the key, and shall not allow the wires to be connected with the battery before the men have been withdrawn from the bottom.

10. In case of a missed or unfired shot (when firing with fuse), he shall not allow any one to descend the shaft until a sufficient time has been allowed to elapse, such time being in no case less than fifteen minutes, and as much longer as he may think necessary, but this shall not apply if the shot was attempted to be fired by electricity. When electrical firing is being used, in case of a miss-fire, he shall disconnect the wires from the battery before descending the pit.

11. After the firing of a sumping or leading shot when firedamp is likely to be given off, the pit shall not be re-entered except with a safety lamp; and after an intermission of working, the pit shall not be entered until a lamp has been lowered to ascertain that no gas has accumulated; and when firedamp may be present safety lamps must be used.

Banksman

1. He shall not leave the top of the shaft while men are in it, and shall give a signal to the men in the bottom when the kibble is a short distance from them.

2. Where a bogie is used it shall be secured by a catch

when on and off, and where doors are used he shall see they are properly closed before tipping the kibble.

3. After the engine has lifted the kibble off the settle boards or bogie, he is to steady it into the pit, and not to put anything into the kibble while hanging in the shaft while men are below.

4. When gear or materials of any description are to be sent down the pit, the Banksman must put them into the kibble when possible, and when necessary fasten them to the bow or chain with a strong tie-band; and when that is not possible, he must properly and safely sling all such materials, walling stones, &c., and steady the kibble or slung material before they leave the top of the shaft.

5. He shall not allow persons to ascend or descend against a loaded kibble, and shall not allow more than the prescribed number of persons to ride at one time, and no person shall ride upon a full kibble, nor upon the edge of the kibble.

Engineman

1. He shall examine the engine and machinery, and all parts connected therewith, within the engine-house, once during each shift.

2. He must not in any case move the engine when men are in the pit, except by a direct order from the Banksman, nor shall he on any account leave the handles whilst the engine is in motion, or allow any other person to touch the handles except by authority from the Manager or Engineer.

3. He shall attend to the safety valves, feed valves, steam and water gauges, and see that the boiler feed is so regulated as to maintain a sufficient supply of water to the boilers.

4. He shall let down and draw up persons with the greatest possible care. When the kibble is going down he shall stop it not less than three fathoms from the bottom, or from any scaffold or cradle where men may be working, until a signal has been given for him to let it down.

5. He must on all occasions stop his engine as soon as he has lifted about four feet from the bottom, in order that the Chargeman may steady the rope; he must not again move

his engine until he has received the proper signal from the Banksman.

6. If he should observe anything faulty or unsafe, he shall send immediately for the Engineer or other responsible person.

7. The Fireman shall be under the entire control of the Engineman.

General Rules

1. Every one in or about the pit shall implicitly obey the orders of the Master Sinker and other officials of the mine.

2. No person shall make any unnecessary noise, or create any disturbance on the pit heap.

3. No intoxicating drink shall be allowed on the works, except in special cases, and then only by order of the Manager, and no intoxicated person shall be allowed to remain on the premises.

4. These Rules are additional to any Special Rules at present in force at the mine, and do not cancel any of the Special or General Rules already in existence under the Coal Mines Regulation Act of 1887, and posted up at the Colliery.

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